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THE COMPOSITION AND STRENGTH OF MORTAR.

By W. J. Dibdin, F.I.C., F.C.S., &c.

THE composition of ordinary lime mortar in relation to the resulting strength is a subject of great importance; yet the attention it has received leaves so much to be yet ascertained that the author feels, in submitting the following facts, that the several points dealt with are not only interesting, but important in the highest degree.

The by-laws of the London County Council regarding the composition of mortar merely specify that it shall be composed of freshly burned lime and clean sharp sand or grit without earthy matter, in the proportions of one of lime to three of sand or grit, but contain no reference to strength, leaving it to be inferred that if the composition is within the strict definition the strength must necessarily be practically constant—quite apart from the particular purpose for which the mortar is to be employed. Further, no "factor of safety" seems to have been considered, so that, whether the mortar be used for a 10-foot wall or one of 100 feet in height, the by-laws equally apply without any precautions.

It may be assumed for the present purpose that a given wall would exert a pressure of 15 lb. to the inch, and if a factor of safety of 5 be taken as reasonable, then it will be necessary to employ a mortar which will resist a crushing weight of $15 \times 5 = 75$ lb. to the inch; and if this is secured the composition of the mortar is of secondary importance; whilst, on the other hand, if the composition be ever so exact, according to an arbitrary standard, it will be inefficient if the strength be too low. For instance, a mortar was carefully prepared with good greystone lime and clean washed sand in the proportions of one part by volume of unslaked lime and three parts of sand; at the end of one month the crushing strength was 38 lb. per cubic inch and only 63 lb. at three months. This result, with many others, is set out in the attached tabular statement of the experiments, Series I., and clearly indicates the danger of mere composition safeguards.

On the other hand, in Series II. are given results obtained by mortar purposely made in direct contradiction to the by-laws—viz. sand to which clay had been added, the proportions of clay varying from $2\frac{1}{2}$ per cent. to 10 per cent.—and this mixture of clay and sand was used in varying proportions up to five volumes to one volume of unslaked lime. At the end of one month the crushing strengths per cubic inch were as follows:—

Sand used					Vol. Sand	Vol. Lime	Crushing Strength, 1 month (lb. per cubic inch)
Neat Brown Leighton Buzzard .	.	.	.	.	5	1	42 lb.
,,	,,	,,	,, + 2½ per cent. clay .	5	1	74 ,,
,,	,,	,,	,,	5 ,, ,, .	5	1	128 ,,
,,	,,	,,	,,	7½ ,, ,, .	5	1	183 ,,
,,	,,	,,	,,	10 ,, ,, .	5	1	176 ,,

These considerations show the necessity for a careful review of the facts.

In order to ascertain these the series of experiments fully set out in the attached tables were conducted. They are necessarily insufficient for a final solution of all the problems which present themselves in the course of such an investigation, but as a preliminary series, involving the making and testing of fourteen hundred briquettes and blocks, they are sufficiently definite for discussion.

The lime used for the initial set of tests A to D in Series I. with Standard Leighton Buzzard sand, as received, had the following composition :—

	Unslaked	Slaked
Silica	5·73	4·11
Oxide of iron and alumina	3·55	2·53
Calcium oxide	87·40	63·08
Carbonic acid	0·12	1·64
Water of hydration, &c.	3·20	28·64
	100·00	100·00

One cubic foot weighed 36·8 lb., and made 1·53 cubic foot slaked lime.

After the briquettes and blocks had been made it was seen that it would simplify the work if a larger quantity of lime was dry-slaked and used for all subsequent tests. This was accordingly done, the sample of lime, invoiced as best " gray lime," being slaked, and kept in an iron box. The analysis of the unslaked lime gave the following factors :—

	Unslaked
Silica, insoluble	1·42
,, soluble	6·83
Oxide of iron and alumina	4·75
Calcium oxide	82·70
Carbonic acid	1·25
Sulphuric acid	0·27
Water of hydration, &c.	2·78
	100·00

1 bushel weighed (unslaked) 54 lb.
1 cubic foot ,, ,, 42 ,,
1 ,, ,, after slaking measured 1·77 cubic foot.

The sands employed were kindly supplied for the purpose of the experiments by Mr. Franklin, Surveyor to the Luton Rural District Council, who sent guaranteed samples of Leighton Buzzard sands :—and three samples of Lewisham sands, kindly supplied by Messrs. H. & G. Taylor. The clay used for the purpose of mixing with the sands in certain of the experiments was ordinary London red clay.

The discussion of the results may be conveniently taken under the following headings :—

1.   Effect of washed sand of varying degrees of fineness.
2.   „   „   varying quantities of clay added to the sand.
3.   „   „   washing out the clay naturally present in sand.
4.   „   „   varying the time when the mortar was used after being first made.
5.   Strength of raw materials employed.
6.   Effect of the variation of the percentage of voids in the sand used.
7.   „   „   composition on spalling.

I. EFFECT OF VARYING THE FINENESS OF THE SAND.

The results of these tests are set out in Series I. For convenience of reference the average results of the tensile and crushing strengths of the briquettes and blocks are set out in the table of average results. The first set, A to D, were made with " Leighton Buzzard Standard Sand," as received. The remainder of the tests were made with the various fractions of this sand which were obtained by washing, drying, and sifting, the meshes varying from $\frac{1}{8}$ inch to below $\frac{1}{75}$ inch. In each case the tests were made in five sets, the variation in each consisting in using different volumes of sand to one volume of unslaked greystone lime—viz. one sand to one lime, two sand, &c., up to five sand to one lime. In every instance three briquettes were made, the breaking fraction being one inch square, and three blocks were used for crushing tests. These blocks or cylinders were conveniently made 1 inch in height and 1·12 inch diameter, thus having practically an area equal to 1 inch square, and may be taken for comparative purposes as being equal to 1-inch cubes. The details of the respective tensile and crushing tests are set out in the tables. Where possible the tests were made at intervals of fourteen days, one month, and three months after the making of the mortar. Notwithstanding the great care taken to ensure constant conditions in the preparation of the respective samples, varying results will necessarily be obtained ; but the averages taken over a prolonged and numerous series must afford reliable indications, especially when, as frequently happens, the *minimum* results in one set will be above the *maximum* in others.

For convenient reference I have set out the results of the average crushing tests at three months in diagram form (Diagram 1). On reference to this it will be seen that mortar made with the proportions of one volume of sand to one volume of lime with the sand unwashed as received had a crushing strength of 150 lb. per cubic inch. When the sand was increased to two volumes the strength fell to 92 lb. per inch. With three volumes sand it was only 52 lb., and with four volumes 53 lb. This experiment alone clearly indicates that an arbitrary limit of three to one is unsatisfactory, as it would prevent the use of the " excess " of lime, which in this case gave three times the crushing strength of that obtained when the by-law proportion of three to one was employed.

In all the subsequent sets of this series the sand was used washed and graded as shown in the tables. The diagram clearly indicates the fact that when the proportions were from one or two of sand to one volume of lime the strength was greater than when three volumes of sand were employed in all those cases in which the sand was coarser than $\frac{1}{30}$ inch ; but when the grading was from $\frac{1}{30}$ inch and below, the strengths of the various makes were practically equal—viz. from 58 to 66 lb. per inch.

The tests for tensile strength are in the same ratio, and clearly indicate that with these particular sands an *excess* of lime in contravention of the by-laws was a distinct advantage.

SERIES II. — THE ADDITION OF CLAY TO SAND.

These tests were very interesting and important. It must be clearly stated at once that in the term "clay" no reference whatever must be inferred to ordinary mould or other extraneous mixtures, but simply and solely to the clay naturally present with ordinary and otherwise clean sand, or to good sound red London clay.

The details of the respective tests are similar to those described under Series I., and the average results of the one month's tests are set out in Diagram II. The first set was made with a sample of Brown Leighton Buzzard sand, as received. As in the former instance, the strength was greatest with the maximum quantity of lime—viz. one volume of sand to one volume of lime, viz. 123 lb. per inch—and gradually fell to 42 lb. for five volumes sand to one volume lime. So that a mortar made with this sand in the proportions of three sand to one lime would have had a strength of only 69 lb. per inch. In the second set of tests with $2\frac{1}{2}$ per cent. added clay, the minimum strength obtained was 74 lb. per inch with five sand to one lime. When the clay was increased to 5 per cent. the corresponding figure was 128 lb., rising to 183 lb. for $7\frac{1}{2}$ per cent. of clay and 176 lb. for 10 per cent. clay, whilst a maximum result of 223 lb. was obtained with 10 per cent. clay and two volumes sand to one lime.

SERIES III.—EFFECT OF REMOVING THE CLAY NATURALLY PRESENT IN SAND.

As it might be assumed that the influence of the clay artificially added would not be the same as of that naturally present, the experiments detailed in Series III. were made, in which trial briquettes and blocks were prepared with the natural sand as received, and after the removal of its adhering clay by washing. Three sands were employed—two with clay and one without. The first two were Lewisham grey and Lewisham red, the third being Lewisham fine white sand. From the diagram it will be seen how the strength of the mortar fell to about one-half its crushing strength when made with the same sand which had been washed to remove its adhering clay, whilst the very fine white sand free from clay gave practically minimum results.

In discussing these effects it must not be overlooked that mortars made with sand containing clay undergo a certain degree of shrinkage on drying, and it will be a matter for discussion as to how far this may be permitted, if at all, in order to utilise the resulting increase of strength. As the greater part of the shrinkage takes place within the first twenty-four hours following the "setting" of the mortar, it will doubtless be of lesser importance than that which might occur at a later date. It would, indeed, seem desirable that a special series of tests on actual brick walls should be made with clayed mortars in order to set the point upon actual experimental data on a working scale, although doubtless there are many architects of great experience who will be able to contribute valuable information on the point.

SERIES IV.—EFFECT OF VARIATION OF TIME BEFORE MORTAR IS USED AFTER BEING MIXED.

The results given in the tabulated Series IV. show the effect of time, up to eleven days, between the moment when the mortar was mixed and that at which the briquettes and blocks were prepared. From these it would seem that up to seven days there is an increased strength, but after that time—that is to say, after the mortar had once set—the effect of a second breaking up was distinctly detrimental, although better results were even then

obtained than at any time before the first setting. The strength at one month gradually rose to 116 lb. per square inch with mortar which had been mixed for seven days, and fell when the mortar had been standing for eleven days to 83 lb.

SERIES V.—STRENGTH OF RAW MATERIALS, *i.e.* LIME AND SAND.

It was thought that it would be interesting to repeat the tensile and crushing tests upon the lime only and on the sands. These tests were therefore made as a matter of interest, and as affording general comparison. The results, as might be anticipated, gave impracticable strengths.

SERIES VI.—EFFECT OF VARIATION OF THE PERCENTAGE OF VOIDS IN THE SAND.

Upon abstracting those tests in which the voids in the sand used had been determined the following results were obtained :—

Sand used	Voids per cent.	One Month	
		Crushing Strength lb. per sq. inch	Tensile Strength lb. per cube inch
Lewisham No. 1	23	154	41
„ No. 2	28	155	32
„ „ washed	30	88	36
Leighton Buzzard, 10 per cent. clay . .	32	202	31
Lewisham No. 1 washed . . .	34	61	33
Leighton Buzzard 5 per cent. clay . . .	36	154	33
Lewisham No. 3	40	70	28

These results are necessarily variable, but from those in which the natural sands only were used, as the washing and addition of clay evidently interfered, the following sequence was obtained :—

Sand used	Voids per cent.	One Month	
		Crushing Strength lb. per sq. inch	Tensile Strength lb. per cube inch
Lewisham No. 1	23	154	41
„ „ 2	28	155	32
„ „ 3	40	70	28

From these facts there is clear evidence that under given conditions the strength of the mortar increases as the percentage of voids decreases. But under other conditions this rule does not hold. It is unfortunate that the importance of this point was not fully realised until a large number of the samples of mortar had been prepared, otherwise the above results might have been considerably enlarged.

The method of ascertaining the percentage of voids was as follows :—

MEASUREMENT OF VOIDS IN SAND BY SPECIFIC GRAVITY METHOD.
Experiment 1: *Standard Leighton Buzzard Sand.*

A 100 c.c. flask was dried and found to weigh 27·950 grammes. It was then filled with dry sand to the 100 c.c. mark and again weighed = 195·25 grammes = 167·30 grammes

sand. The sand was then turned out into a dry beaker and the flask partly filled with distilled water, and the sand then gradually poured back into the flask. As the water rose above the 100 c.c. mark the excess was removed until the whole of the sand was returned to the flask and the water-line stood exactly at the mark, the sand having slightly shrunk in volume. The weight was now found to be 231·550 grammes, which, minus the weight of the flask, indicated 167·300 grammes of sand and 36·300 grammes of water, or, in terms of *volume*, 100 c.c. sand to 36·3 c.c. water; and as the number of c.c. of water represent the voids in the sand these necessarily equalled 36·3 per cent. Shortly this factor is arrived at immediately by deducting the weight of the flask filled with the sand from that of the flask filled with the sand and water, viz.—

$$
\begin{array}{lr}
\text{Flask + Sand + Water} & \quad 231\cdot55 \\
\text{Flask + Sand} & \quad 195\cdot25 \\[4pt]
\text{Voids per cent.} & \quad 36\cdot30
\end{array}
$$

For the purpose of strict accuracy a correction should be made for the difference in volume between the dry and the wet sand. This is done by adding sufficient sand to the flask after the weighing of the sand + water to raise the volume of sand to the mark: a weighing is now made, when in the case cited the increase due to the sand was found to be 2·21 grammes, which added to the first weighing of flask and sand increased the result from 195·25 to 197·46. The excess of water thus raised above the water-line was then thrown out and a weighing again made, when it was 232·770 grammes. The difference between these two results gave 35·31 per cent. for the voids, a difference which is negligible for practical purposes.

The same result may be arrived at on the basis of the specific gravity. In the above case the sp. gr. of the sand was found to be 2·626. The weight of 1,000 c.c. of the dry sand was 1,673 grammes, and $\dfrac{1673}{2626} = 0\cdot637$, which, deducted from 1,000, gives 36·3 for the percentage of voids, which agrees with the above for dry sand. If the sand is weighed wet then we have $\dfrac{1695}{2626} = 0\cdot646$, which deducted from 1·000 gives 35·4.

The most simple method is therefore to place the sand in a glass cylinder marked in separate divisions up to 200 measures. Run the sand in its natural condition into the cylinder, so that when shaken down into its naturally compressed condition it measures 100 divisions. Then remove the sand and fill up to the 100 mark with clean water. Then gradually pour the sand into the water and shake down. Note the height to which the water rises and the volume the sand now measures under water. The total volume thus measured *minus* the sum of the volumes of the water taken and the volume of sand as measured under water gives the voids in terms of percentages volume thus:—

$$
\begin{array}{lr}
\text{Sand taken} & = 100\cdot0 \text{ c.c.} \\
\text{Water ,,} & = 100\cdot0 \text{ ,,} \\
\text{Volume of mixed sand and water} & = 163\cdot7 \text{ ,,} \\
\text{,, ,, sand under water} & = 99\cdot0 \text{ ,,} \\[6pt]
\therefore \text{ Voids} = \text{Sand under water + water} & 199\cdot0 \text{ ,,} \\
\text{\textit{Less} volume of mixed sand and water} & 163\cdot7 \text{ ,,} \\[4pt]
& 35\cdot3 \text{ per cent.}
\end{array}
$$

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THE COMPOSITION AND STRENGTH OF MORTAR. [W. J. DIBDIN.]

SERIES I. VARIANT FINENESS OF SAND.
CRUSHING STRENGTHS AT 3 MONTHS.

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THE COMPOSITION AND STRENGTH OF MORTAR. [W. J. DIBDIN.]
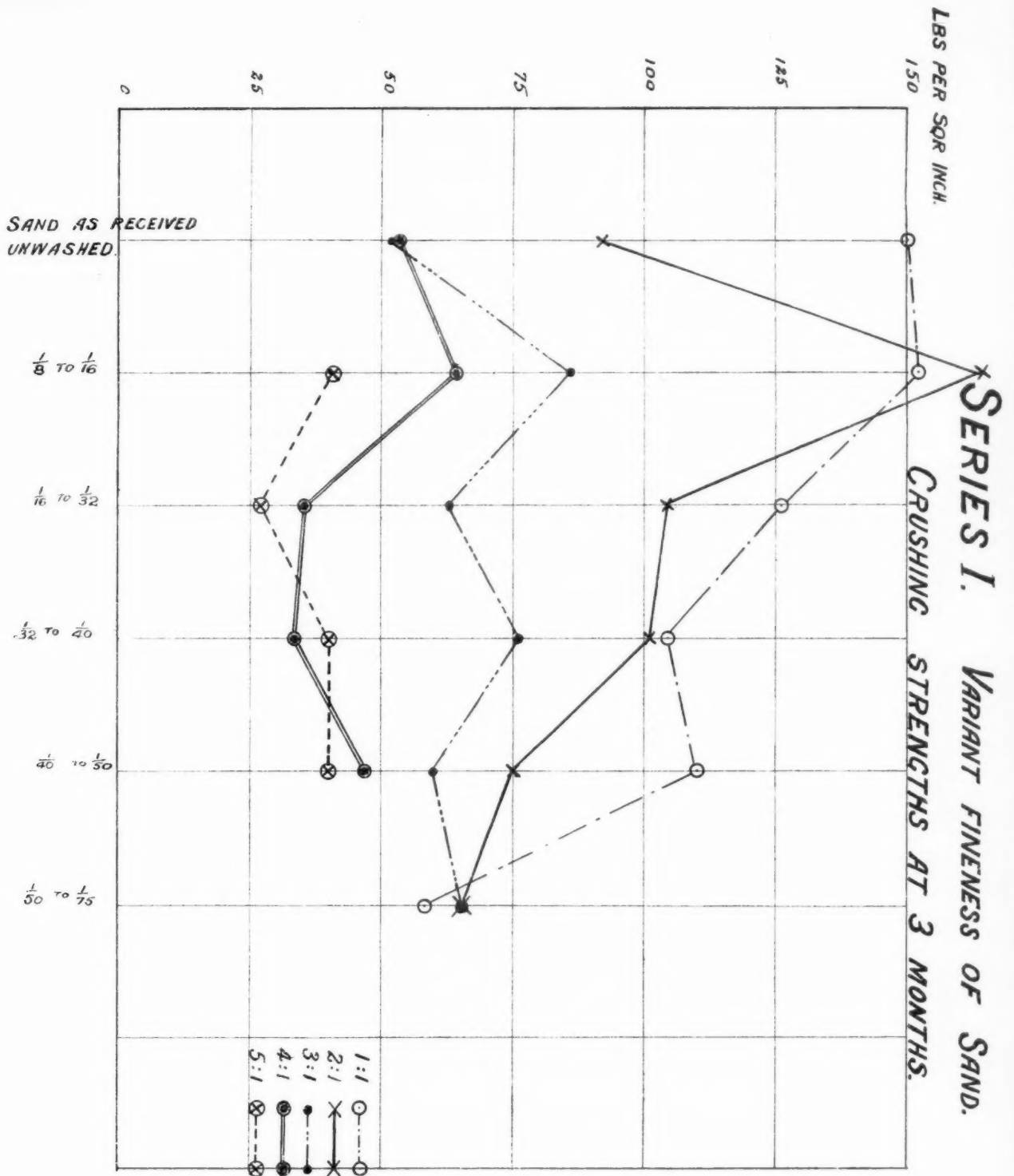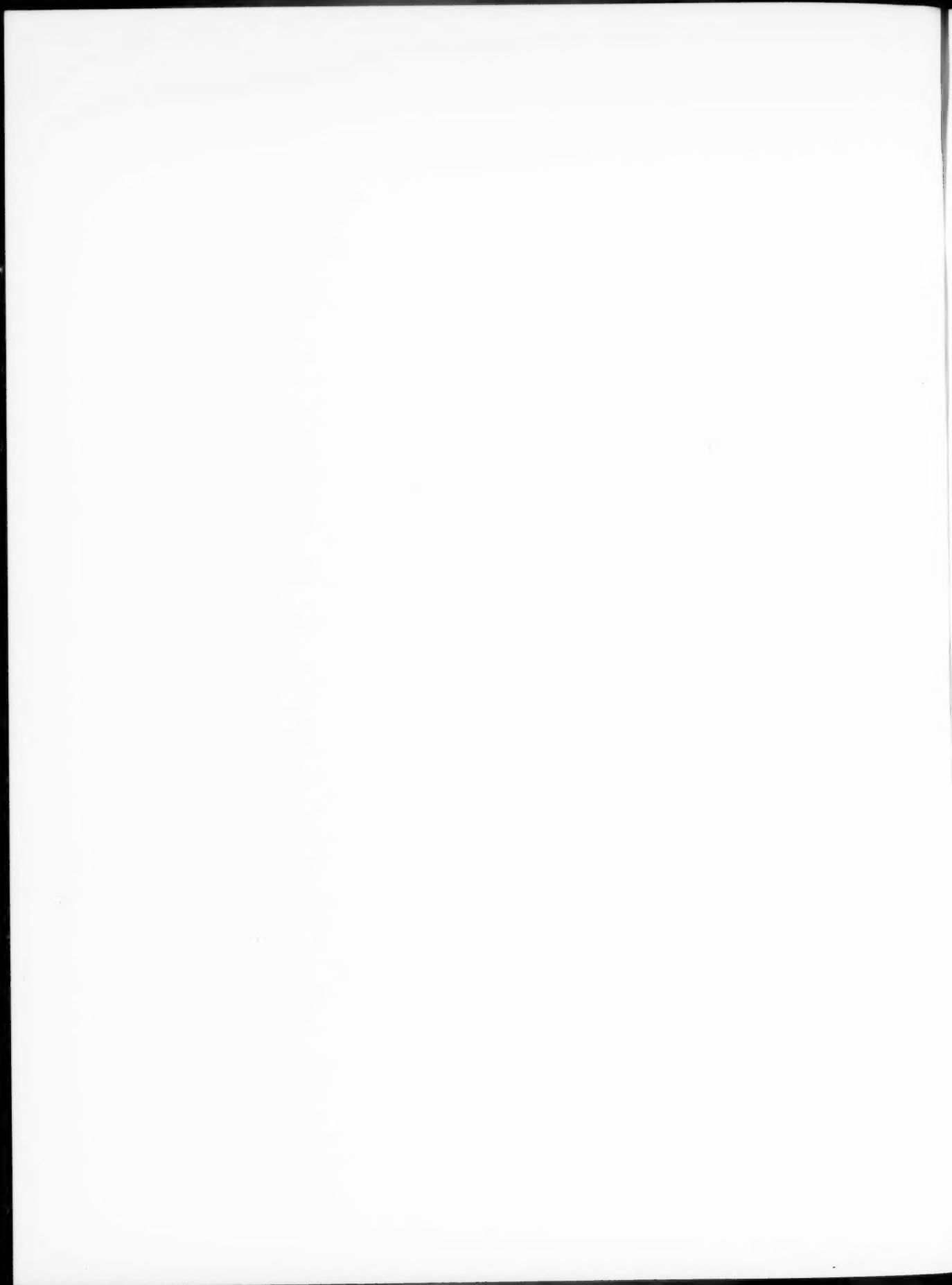
SERIES II — LEIGHTON BUZZARD SAND. VARIANT – CLAY. CRUSHING STRENGTH AT 1 MONTH.

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THE COMPOSITION AND STRENGTH OF MORTAR. [W. J. DIBDIN.]
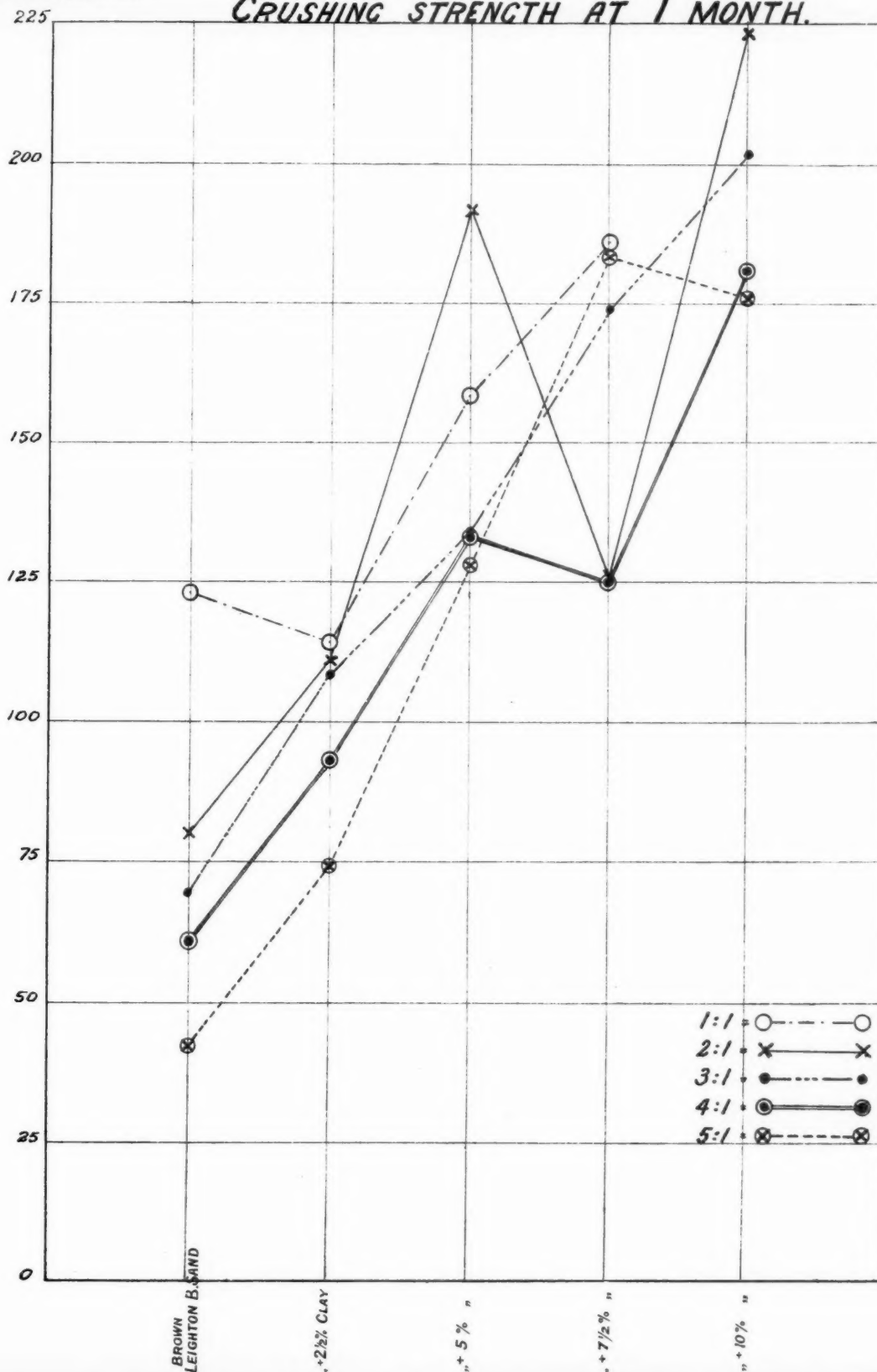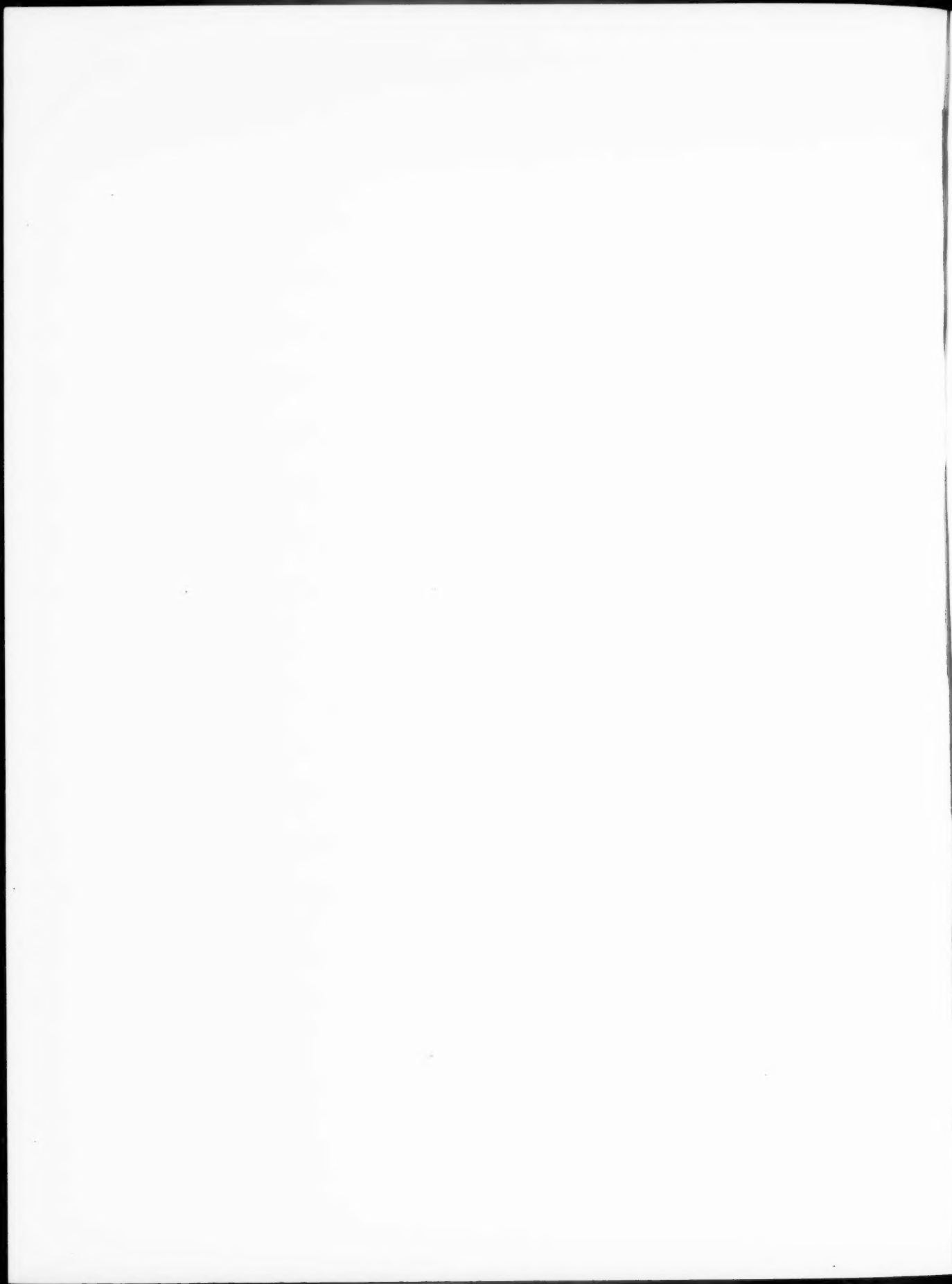
SERIES III. LEWISHAM SAND.
VARIANT. – CLAY.
CRUSHING STRENGTHS AT 1 MONTH.

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THE COMPOSITION AND STRENGTH OF MORTAR. [W. J. DIBDIN.]
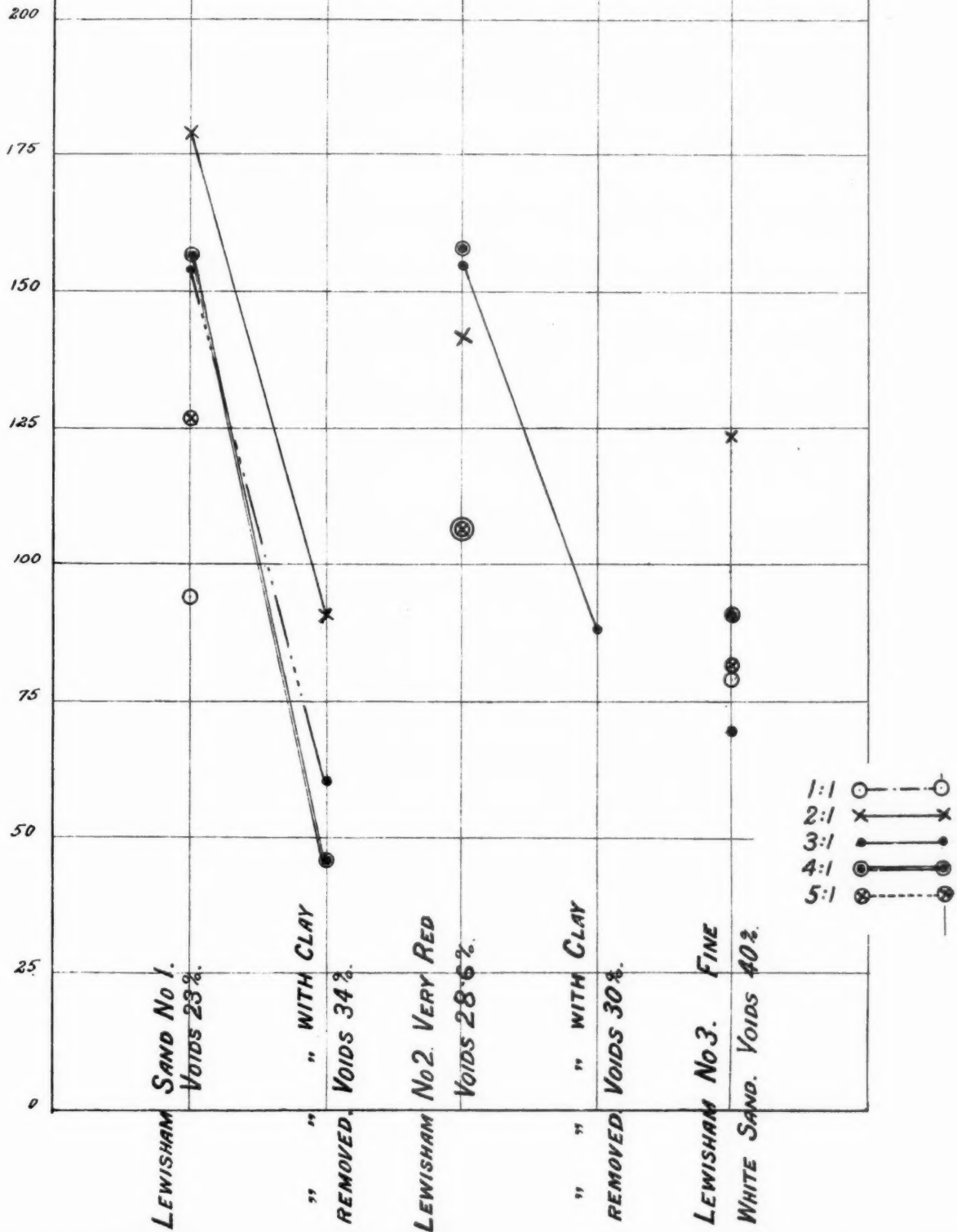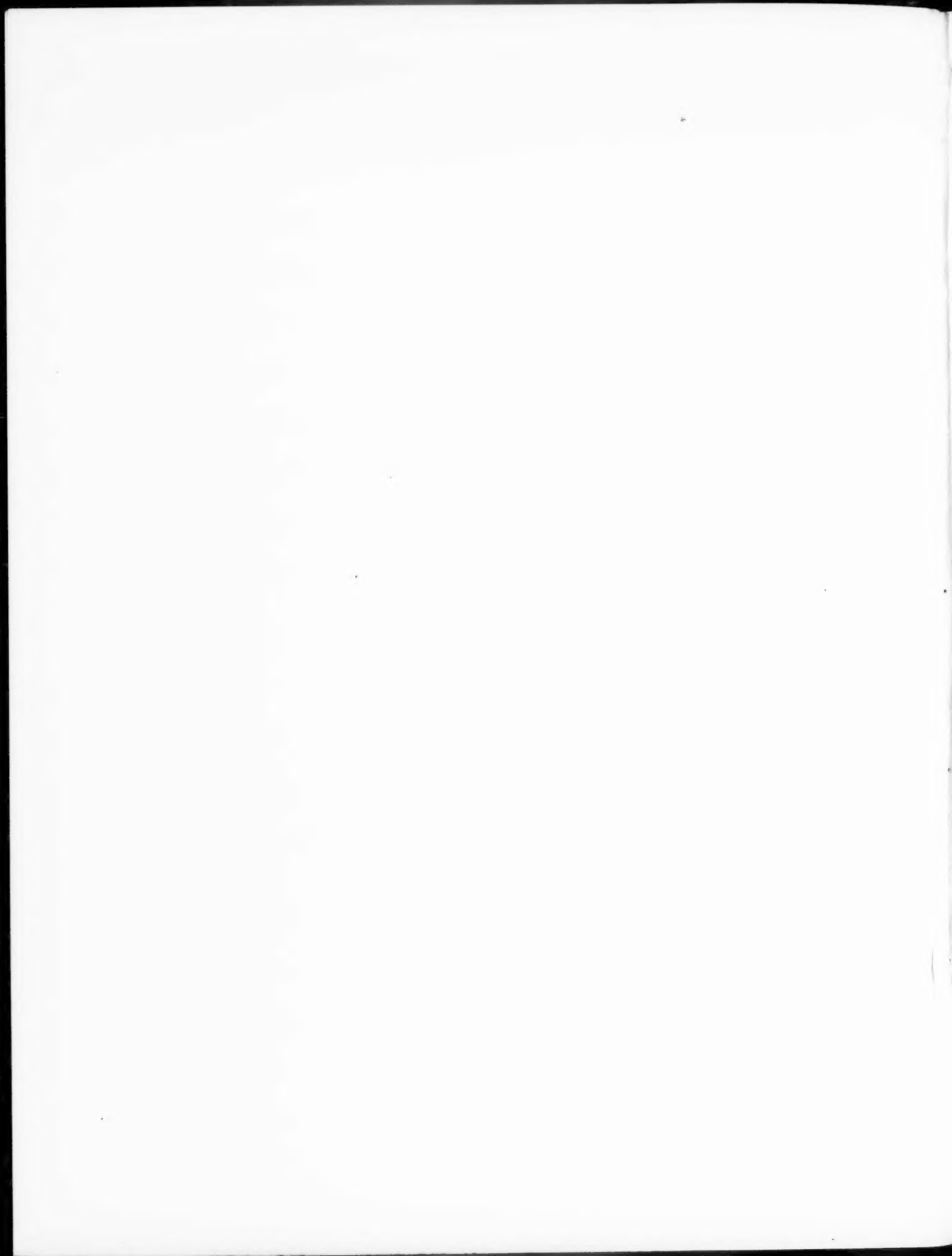
EFFECT OF VOIDS IN NATURAL SAND.
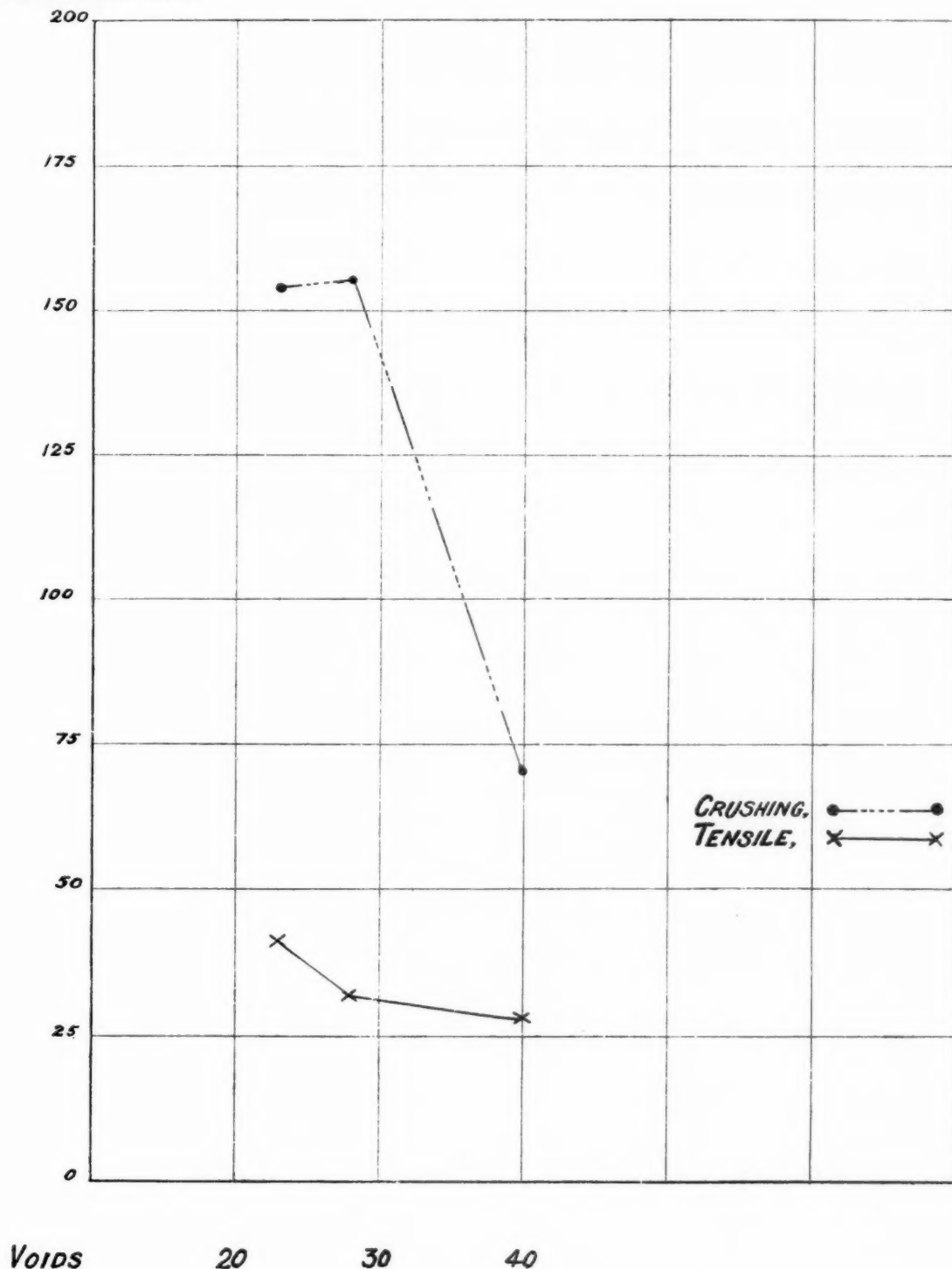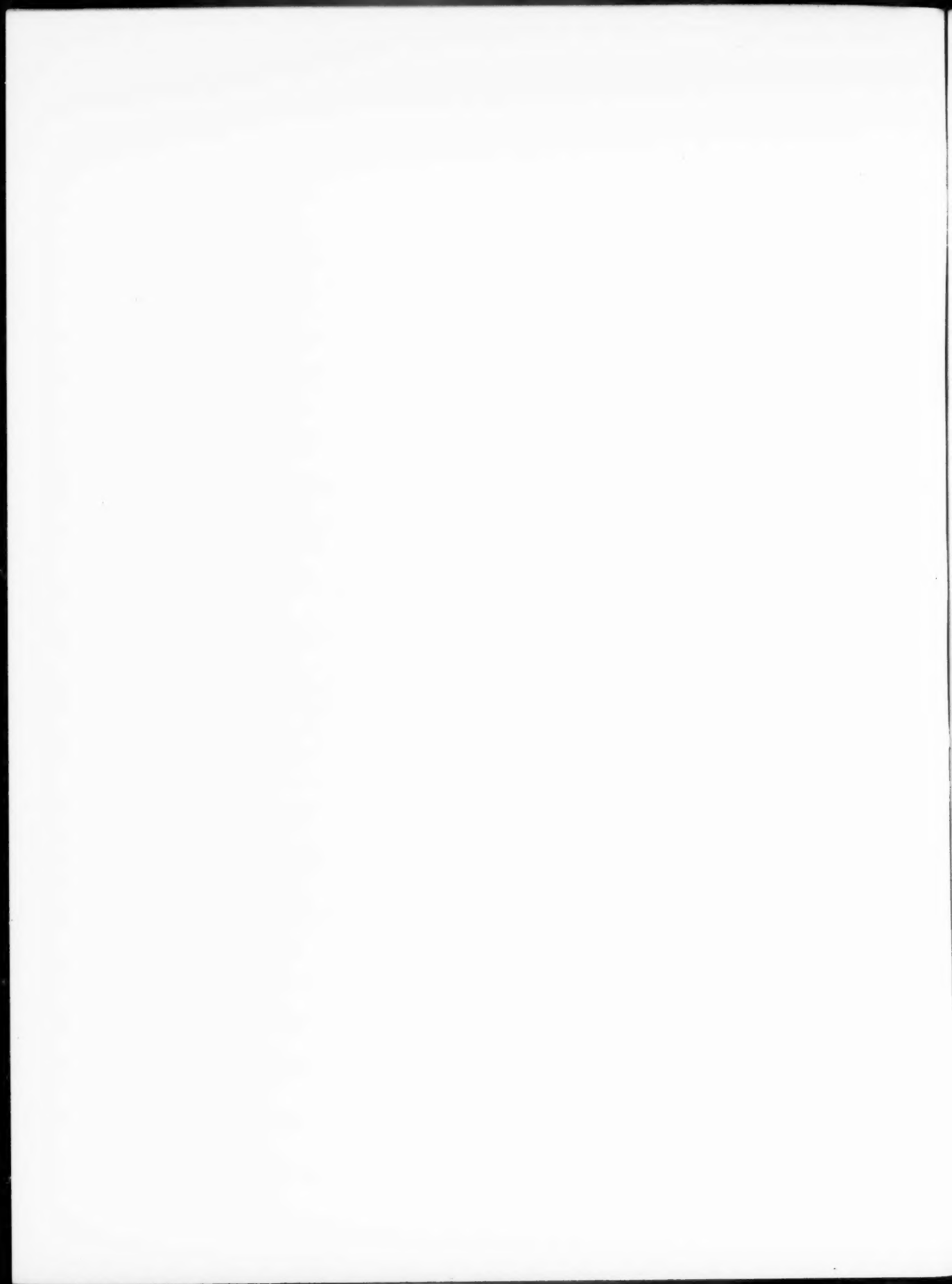
Spalling.

When clean sand is used spalling happens practically with over-limed mortars; in other cases the blocks burst in the crushing tests without notice. When clay was used with the sand, spalling steadily occurs. The method adopted for determining the pressure at which spalling occurred was to observe the time in seconds at which the spalling commenced, and also that at which crushing took place. As the pressure was steadily increased throughout the test by the constant rate of addition of a stream of shot, a simple rule-of-three calculation gave the pressure at which spalling occurred. The results in each case are set out in detail in the tables, the figure "0" indicating that no spalling took place. The fact that when clay was present ample notice of crushing was given by preliminary spalling may afford a valuable index in practice of the danger point; but this is a practical point more fitted for discussion by the architect than the chemist.

Conclusion.

From the above results of a fairly exhaustive series of tests, so far as the limits of the experiments extend, it seems clear that the strength of a mortar depends far more upon the physical character of the materials employed than has hitherto been fully realised. If the usual prescription of three to one be rigidly adhered to, the mortar may have in certain cases only one-third of the strength of that which might be obtained with as widely varying proportions as five of sand to one of lime, as already indicated; and it would appear to be desirable that the *strength* as ascertained by crushing rather than arbitrary proportions should be the *criteria*. The tests can be made with great facility, and should be employed in all cases. Of course it is not suggested that any and every admixture should be sanctioned, but where the materials are clean and sound and free from dirt (such as unwashed road sweepings, dustbin refuse, old mortar, &c.) no unreasonable objection should be taken to their use provided that they yield a mortar having strength sufficient for the work in hand. If a factor of safety of five be sufficient for any work, it is obviously unnecessary to ask for one of ten, as the strength upon that basis must necessarily increase with the increment of the load. On the other hand care should be exercised to secure such factor of safety as may be required in any particular case.

Effect of Addition of Clinker.

It is a common practice to add hard clinkers crushed in a mill to the sand, sometimes in even equal quantities. Experiments conducted on the same lines as those detailed above confirm the general conclusions in regard to fineness—varying quantities of sand and grit to lime, &c.—and show that mortars made with good hard clinker and sand may be used with safety.

RESULTS OF MORTAR ENQUIRY, 1906.

SERIES I.—VARIANT, FINENESS OF SAND.

Laboratory Numbers	Description: Sand — Sand	Description: Sand — Grading	Lime — Volumes of Sand	Lime — Volumes of Unslaked Lime	Tensile Strength (Lb. per Square Inch) — Fourteen Days	One Month	Three Months	Crushing Strength (Lb. per Cube Inch) — Fourteen Days Spalled	Fourteen Days Crushed	One Month Spalled	One Month Crushed	Three Months Spalled	Three Months Crushed
A	Leighton Buzzard Standard Sand	Standard 1/20 inch to 1/30 inch	1	1	{28/26/25} 26	—	{30/30/25} 28	—	{107/97/94} 99	—	—	—	{149/179/122} 150
B			2	1	{29/33/31} 31	—	{30/30/35} 32	—	{119/75/—} 97	—	—	—	{90/81/106} 92
C			3	1	—	—	{20/20/25} 22	—	—	—	—	—	{52/58/45} 52
D			4	1	—	—	{15/15/17/14} 15	—	—	—	—	—	{65/44/50} 53
E 1	Leighton Buzzard Washed	1/8 inch to 1/16 inch	1	1	—	—	—	{31/0/62}	{62/94/106} 87	{120/0/120}	{150/150/137} 146	{0/141/142}	{147/158/150} 152
E 2			2	1	{28/23/20} 24	{30/40/35} 35	—	{0/69/0}	{94/78/125} 99	{0/82/5}	{50/97/75} 74	{0/0/0}	{182/131/178} 164
E 3			3	1	—	—	—	{0/0/0}	{59/73/44} 59	{0/0/0}	{50/62/56} 56	{0/0/0}	{76/95/87} 86
E 4			4	1	{26/30/10} 22	—	—	{0/0/0}	{50/50/37} 46	{0/0/0}	{40/37/22} 33	{0/0/0}	{67/60/65} 64
E 5			5	1	—	—	—	{0/18/15}	{25/34/40} 33	{0/0/0}	{44/31/28} 34	{0/41/0}	{36/45/41} 41
F 1	Leighton Buzzard Washed	1/16 inch to 1/32 inch	1	1	{18/21/32} 24	{38/38/40} 39	{48/48/46} 47	{0/94/75}	{116/100/87} 101	{120/108/103}	{137/128/115} 127	{0/68/0}	{126/102/148} 126
F 2			2	1	{24/18/18} 20	{22/17/20} 20	{20/26/34} 27	{0/0/0}	{78/53/59} 63	{59/60/77}	{65/65/84} 72	{105/76/91}	{125/87/100} 104
F 3			3	1	{34/?/20} 27	{20/18/15} 18	{24/20/24} 23	{50/0/?}	{59/40/65} 55	{36/0/0}	{44/25/44} 38	{0/0/49}	{52/81/55} 63
F 4			4	1	{16/6/14} 12	{18/17/23} 19	{26/—/10} 18	{0/0/0}	{44/28/37} 36	{0/0/0}	{50/31/25} 35	{0/0/0}	{32/42/31} 35
F 5			5	1	{5/12/10} 9	{10/12/—} 11	{8/10/—} 9	{0/0/0}	{28/31/25} 28	{0/0/0}	{15/18/22} 19	{0/0/0}	{34/15/30} 27
G 1	Leighton Buzzard Washed	1/32 inch to 1/64 inch	1	1	{32/28/30} 30	{30/35/—} 32	{46/42/40} 43	{68/81/100}	{90/97/118} 102	{90/101/76}	{131/103/144} 126	{0/0/0}	{78/125/110} 104
G 2			2	1	{20/18/30} 23	{20/25/25} 23	{46/42/44} 42	{56/47/0}	{71/75/56} 64	{0/0/0}	{94/72/56} 67	{45/0/75}	{99/84/118} 101
G 3			3	1	{18/6/16} 13	{15/12/20} 16	{28/10} 19	{0/25/31}	{62/43/59} 55	{0/0/0}	{78/40/75} 64	{0/0/0}	{95/71/62} 76
G 4			4	1	{10/18/12} 13	{10/12/10} 11	3	{0/0/0}	{31/44/28} 29	{0/0/16}	{44/44/34} 41	{0/0/0}	{33/33/33} 33
G 5			5	1	{8/10/6} 8	{under 10 average}	—	{0/0/0}	{28/37/25} 31	{0/0/0}	{40/40/22} 30	{0/0/0}	{40/40/40} 40

SERIES I.—VARIANT, FINENESS OF SAND (continued).

Laboratory Numbers	Sand	Grading	Volumes of Sand	Volumes of Unslaked Lime	Tensile Fourteen Days	Tensile One Month	Tensile Three Months	Crushing 14 Days Spalled	Crushing 14 Days Crushed	Crushing 1 Month Spalled	Crushing 1 Month Crushed	Crushing 3 Months Spalled	Crushing 3 Months Crushed
H 1	Leighton Buzzard Washed	1/40 inch to 1/10 inch	1	1	{18,18,16} 17	{25,25,25} 25	{30,38,38} 35	{?,50,0}	{68,53,50} 57	{57,0,0}	{59,87,87} 78	{0,0,84}	{91,128,110} 110
H 2			2	1	{34,26,24} 28	{30,25,30} 28	{50,50,30} 43	{0,0,0}	{78,62,68} 69	{36,0,0}	{44,50,47} 47	{45,0,75}	{64,75,86} 75
H 3			3	1	{6,10,14} 10	{25,25,20} 23	{30,30,22} 27	{0,0,0}	{53,40,50} 48	{0,0,0}	{40,47,53} 47	{0,0,0}	{54,60,65} 60
H 4			4	1	{6,—,—} 6	{15,—,—} 15	—	{0,0,0}	{31,25,37} 31	{0,0,0}	{28,22,28} 26	{0,0,0}	{40,50,50} 47
H 5			5	1	{10,4,6} 7	under 10 average	—	{0,0,0}	{62,34,22} 39	{0,0,0}	{44,28,19} 30	{0,0,0}	{47,27,46} 40
I 1	Leighton Buzzard Washed; Voids, 35 per cent.	1/10 inch to 1/5 inch	1	1	—	—	—	{18,18,25}	{37,43,50} 43	{44,0,67}	{50,81,72} 68	{0,0,0}	{62,46,66} 58
I 2			2	1	{20,20,26} 22	{30,28,—} 29	—	{50,43,47}	{84,71,62} 72	{0,0,0}	{81,72,72} 75	{0,0,0}	{66,69,64} 66
I 3			3	1	—	—	—	{43,?,31}	{50,50,43} 48	{0,0,0}	{62,62,59} 61	{0,0,31}	{89,55,54} 66
I 4			4	1	{14,14,16} 15	{12,14,15} 14	—	{0,0,0}	{26,25,?} 25	{0,0,27}	{37,32,30} 33	—	—
I 5			5	1	—	—	—	{0,0,0}	{31,30,25} 29	{0,0,0}	{31,37,31} 33	—	—
J 1	Leighton Buzzard Washed	Passed 1/5 inch	1	1	—	—	—	{0,0,0}	{44,69,66} 60	{48,46,0}	{72,57,72} 67	—	—
J 2			2	1	—	—	—	{0,57,0}	{91,62,94} 82	{78,0,0}	{87,52,62} 67	—	—
J 3			3	1	—	—	—	{0,0,11}	{19,22,34} 25	{0,0,24}	{28,27,27} 27	—	—
J 4			4	1	—	—	—	{0,?,0}	{25,?,28} 26	{0,0,15}	{19,15,19} 18	—	—
J 5			5	1	—	—	—	{0,0,0}	{65,62,68} 65	{0,0,0}	{37,37,37} 37	—	—

SERIES II.—VARIANT, CLAY.

Laboratory Numbers	Sand	Grading	Volumes of Sand	Volumes of Unslaked Lime	Tensile Fourteen Days	Tensile One Month	Tensile Three Months	Crushing 14 Days Spalled	Crushing 14 Days Crushed	Crushing 1 Month Spalled	Crushing 1 Month Crushed	Crushing 3 Months Spalled	Crushing 3 Months Crushed
K 1	Leighton Buzzard Brown	Weight. Vol. / trace trace / 1/4 . 4 0·3 % / 1/8 . 14 1·0 % / 1/15 . 60 5·0 % / 1/30 . 111 7·0 % / 1/60 . 1,285 87·0 % / 1/72 . 110 7·3 % / Pass 1/72 . 25 3·6 % / 1,609 111·2 %	1	1	{30,30,30} 30	{30,30,36} 32	{50,45,45} 47	{81,0,117}	{85,142,120} 116	{61,125,102}	{104,130,135} 123	{0,65,78}	{137,110,97} 115
K 2			2	1	{25,lost,20} 22	{28,26,22} 25	{35,—,25} 30	{0,0,0}	{75,78,77} 77	{0,70,0}	{61,85,95} 80	{95,0,0}	{104,104,47} 85
K 3			3	1	{30,22,20} 24	{32,33,31} 32	{30,30,32} 31	{9,0,0}	{75,96,75} 82	{0,0,0}	{79,79,50} 69	{0,0,0}	{53,87,93} 78
K 4			4	1	{32,27,18} 26	{18,18,26} 21	{38,40,20} 33	{0,0,0}	{62,54,59} 58	{0,0,0}	{65,59,59} 61	{0,0,0}	{68,50,63} 60
K 5			5	1	{15,15,lost} 15	{18,16,14} 16	{20,20,20} 20	{0,0,0}	{54,47,50} 50	{0,0,0}	{42,39,44} 42	{0,0,0}	{31,33,34} 33

Q

SERIES II.—VARIANT, CLAY (*continued*).

Laboratory Numbers	Sand	Grading	Volumes of Sand	Volumes of Un-slaked Lime	Tensile: Fourteen Days	Tensile: One Month	Tensile: Three Months	Crush 14d Spalled	Crush 14d Crushed	Crush 1mo Spalled	Crush 1mo Crushed	Crush 3mo Spalled	Crush 3mo Crushed
L 1	Leighton Buzzard Brown +2·5 per cent. Clay ground to pass ⅛ inch	As "K" + Clay	1	1	{36,45,45} 42	{55,40,38} 44	{100,80,85} 88	{58,72,73}	{84,79,107} 90	{82,68,101}	{100,102,139} 114	{95,116,117}	{143,152,126} 140
L 2			2	1	{20,20,20} 20	{30,25,24} 26	{32,22,48} 34	{0,0,0}	{107,91,96} 98	{0,0,0}	{121,97,114} 111	{0,0,80}	{75,56,96} 76
L 3			3	1	{30,30,35} 32	{33,20,34} 29	{52,50,45} 49	{0,0,0}	{71,70,99} 80	{0,0,0}	{101,95,128} 108	{0,0,0}	{75,156,112} 114
L 4			4	1	{30,30,28} 30	{18,22,36} 25	{48,40,50} 46	{0,0,0}	{72,77,67} 72	{0,0,0}	{80,107,91} 93	{0,0,0}	{69,81,119} 90
L 5			5	1	{32,30,28} 30	{32,36,43} 37	{50,60,60} 57	{0,0,0}	{55,78,66} 66	{0,0,0}	{86,65,72} 74	{0,0,0}	{75,62,65} 67
V 1	Leighton Buzzard +5 per cent. Clay. Voids, 36 per cent.	As "K" + Clay	1	1	{20,40,36} 32	{58,56,30} 48	{100,110,110} 107	{65,73,61}	{115,130,122} 122	{0,0,126}	{154,178,143} 158	{135,143,163}	{210,237,253} 233
V 2			2	1	{36,32,35} 34	{34,50,38} 41	{65,80,110} 85	{0,0,0}	{185,199,159} 181	{143,0,0}	{171,205,203} 192	{257,171,0}	{300,200,150} 217
V 3			3	1	{28,35,30} 31	{26,42,34} 33	{90,42,64} 65	{0,0,0}	{105,107,121} 111	{103,101,113}	{119,156,127} 134	{85,86,0}	{130,125,161} 139
V 4			4	1	{40,50,35} 42	{60,32,50} 47	{92,76,—} 84	{71,0,0}	{89,90,84} 88	{74,107,107}	{106,150,142} 133	{167,65,—}	{175,130,—} 153
V 5			5	1	{30,36,38} 35	{60,60,60} 60	{80,68,—} 74	{113,0,0}	{122,87,97} 102	{91,0,88}	{120,148,117} 128	{82,0,0}	{131,112,81} 108
W 1	Leighton Buzzard +7·5 per cent. Clay	As "K" + Clay	1	1	{20,20,20} 23	{66,20,30} 39	{65,65,65} 65	{0,0,0}	{149,169,117} 145	{111,0,170}	{180,193,184} 186	{173,150,140}	{191,175,210} 192
W 2			2	1	{36,32,30} 32	{50,34,50} 45	{90} 90	{0,0,0}	{101,89,90} 93	{117,—,—}	{126,—,—} 126	{119,146,125}	{153,187,200} 180
W 3			3	1	{40,46,40} 42	{72,32,60} 55	{120,92,122} 111	{0,0,0}	{135,153,97} 128	{143,145,95}	{151,159,212} 174	{300,216,187}	{311,264,240} 272
W 4			4	1	{29,30,18} 26	{42,26,20} 29	{72,74,70} 72	{74,0,0}	{84,65,107} 86	{69,127,101}	{78,191,115} 125	{100,0,0}	{159,102,105} 122
W 5			5	1	{24,46,46} 38	{60,40} 50	{64,60} 62	{85,0,0}	{117,87,150} 118	{0,162,136}	{200,188,160} 183	{148,180,206}	{198,204,228} 207
X 2	Leighton Buzzard +10 per cent. Clay. Voids, 32½ per cent.	As "K" + Clay	2	1	{28,28,52} 36	{40,42,50} 43	{95,90,70} 85	{0,0,163}	{137,156,177} 157	{0,177,0}	{221,200,247} 223	{210,222,0}	{247,270,287} 261
X 3			3	1	{34,—,28} 31	{52,70,35} 52	{90,130,40} 90	{127,147,109}	{142,184,163} 163	{210,0,0}	{238,180,187} 202	{0,152,0}	{190,206,252} 228
X 4			4	1	{38,42,54} 45	{50,38} 44	{92,102,80} 91	{0,0,43}	{136,161,77} 125	{0,182,104}	{102,210,120} 181	{217,0,0}	{242,207,250} 233
X 5			5	1	{46,33,48} 43	{80,50,65} 65	{88,88,88} 88	{109,0,100}	{134,87,134} 118	{0,0,154}	{203,160,165} 176	{0,191,147}	{274,246,183} 234

SERIES III.—LEWISHAM SANDS. VARIANT, CLAY.

Laboratory Number	Description — Sand	Grading	Volumes of Sand	Volumes of Unslaked Lime	Tensile 14 Days	Tensile One Month	Tensile Three Months	Crush 14 Days Spalled	Crush 14 Days Crushed	Crush One Month Spalled	Crush One Month Crushed	Crush Three Months Spalled	Crush Three Months Crushed
N 1			1	1	22/26/25 – 24	24/18/26 – 23	70/80/70 – 73	52/43/44	78/69/53 – 67	82/81/0	92/91/98 – 94	115/122/0	140/175/160 – 158
N 2	Lewisham No. 1. Voids, 23 per cent.	Retained on ½″ 1·0 %; ¼″ 1·0 %; ⅒″ 1·1 %; 1·0 %; 29·7 %; 45·0 %; Passed 17·3 %; 96·1 %	2	1	—/32/28 – 30	30/36/42 – 36	100/80/— – 90	0/0/0	178/122/110 – 137	128/140/0	165/175/190 – 179	0/145/0	230/175/190 – +233 / +294
N 3			3	1	33/32/30 – 32	42/42/38 – 41	60/70/— – 65	0/0/0	87/90/80 – 86	0/0/84	240/98/123 – 154	148/0/0	159/106/110 – 125
N 4			4	1	38/35/40 – 38	40/42/46 – 43	60/50/— – 55	93/0/94	100/108/103 – 104	130/0/0	153/185/132 – 157	0/0/0	212/138/175 – 175
N 5			5	1	40/39/34 – 38	48/50/53 – 50	55/60/60 – 58	0/0/0	117/107/72 – 99	0/0/0	121/148/112 – 127	105/0/0	119/163/111 – 131
R 2		Retained on ½″ 0·0 %; 2·0 %; 1·1 %; 0·7 %; 0·8 %; 28·7 %; 55·0 %; Passed 14·2 %; 102·5 %	2	1	30/30/30 – 30	30/36/24 – 30	35/40/55 – 43	0/0/0	98/110/110 – 106	0/62/80	97/89/88 – 91	0/82/75	126/106/100 – 111
R 3	Lewisham No. 1 with clay removed. Voids, 34 per cent.		3	1	35/30/25 – 30	35/35/30 – 33	65/60/45 – 59	0/0/0	77/61/58 – 65	37/0/0	46/43/95 – 61	0/0/0	72/100/89 – 87
R 4			4	1	15/20/18 – 18	22/27/25 – 24	40/30/45 – 38	26/0/65	37/34/35 – 35	0/0/0	38/29/70 – 46	0/0/40	44/44/50 – 46
P 1			1	1	30/32/30 – 31	29/35/30 – 35	85/95/70 – 83	54/28/38	100/58/73 – 77	70/0/0	84/118/120 – 107	175/106/185	210/165/244 – 206
P 2		Retained on ½″ 0·0 %; 5·7 %; 7·1 %; 11·2 %; 12·8 %; 52·8 %; 9·7 %; Passed 4·8 %; 104·1 %	2	1	24/26/26 – 25	48/30/30 – 36	70/80/90 – 80	0/0/0	100/70/65 – 78	0/143/0	132/161/132 – 142	140/101/0	195/202/194 – 194
P 3	Lewisham No. 2. Very red. Voids, 28·6 per cent.		3	1	33/23/— – 28	38/30/28 – 32	60/70/60 – 63	0/0/0	131/132/125 – 129	0/0/0	161/160/145 – 155	98/0/89	167/192/219 – 193
P 4			4	1	28/20/30 – 26	28/40/35 – 34	50/40/55 – 48	0/0/0	156/165/141 – 154	0/0/0	154/192/129 – 158	0/0/160	116/130/175 – 138
P 5			5	1	30/22/28 – 27	20/28/40 – 29	35/40/35 – 37	0/0/0	73/92/127 – 97	0/91/51	127/100/93 – 107	62/0/48	77/106/97 – 93
S 3	Lewisham No. 2. Clay washed out. Voids, 30 per cent.	Retained on ½″ 0·0 %; 5·0 %; 6·0 %; 14·0 %; 12·0 %; 50·7 %; 9·0 %; Passed 4·6 %; 101·3 %	3	1	32/30/40 – 34	36/40/32 – 36	30/60/30 – 40	82/0/0	89/85/75 – 83	0/0/96	92/72/100 – 88	72/0/0	81/57/100 – 79
T 1			1	1	20/15/20 – 18	30/20/18 – 23	80/84/80 – 82	0/0/0	41/72/82 – 65	0/0/0	78/73/85 – 79	93/0/99	112/141/124 – 126
T 2		Retained on ⅒″ trace; Passed 1·0 %; 99·0 %; 100·0 %	2	1	28/27/20 – 25	36/30/32 – 33	46/54/62 – 54	0/0/94	110/172/90 – 124	93/0/94	104/147/117 – 123	0/160/138	153/184/190 – 176
T 3	Lewisham No. 3. Very fine, natural white sand. Voids, 40 per cent.		3	1	22/23/24 – 23	28/30/26	50/48/60 – 53	0/0/0	70/93/77 – 80	53/0/0	63/102/44 – 70	83/97/94	100/115/122 – 112
T 4			4	1	19/22/22 – 21	8/30/10 – 16	38/50/48 – 45	0/0/0	71/87/62 – 74	0/0/0	90/60/122 – 91	0/103/86	94/112/112 – 106
T 5			5	1	20/18/20 – 19	16/30/20 – 24	40/50/36 – 42	0/0/0	70/61/82 – 71	0/30/0	91/50/104 – 82	0/0/—	73/90/— – 82

SERIES IV.—VARIANT, TIME.

MORTAR MADE, AND BRIQUETTES AND BLOCKS MADE THEREFROM AT DIFFERENT PERIODS.

Laboratory Numbers	Description — Sand	Grading	Volumes of Sand	Lime — Volumes of Un-slaked Lime	Tensile Strength (Lb. per Square Inch) — Fourteen Days	One Month	Three Months	Crushing Strength (Lb. per Cube Inch) — Fourteen Days — Spalled	Crushed	One Month — Spalled	Crushed	Three Months — Spalled	Crushed
U 1	Brown Leighton Buzzard Sand used at once		3	1	—	(30), 5, 6) = 14	(50), 48, 42) = 47	0, 0, 0	64, 95, 65) = 75	0, 0, 0	95, 40, 55) = 63	49, 116, 0	73, 125, 78) = 89
U 2	Ditto, one day standing (no water added)		3	1	(24, 23, 23) = 23	(26, 34, 30) = 30	(42, 50, 44) = 45	0, 0, 0	72, 80, 69) = 74	0, 31, 0	41, 46, 75) = 54	0, 0, 0	112, 69, 109) = 97
U 3	Ditto, two days standing (damped)		3	1	(24, 23, 23) = 23	(20, 34, 28) = 28	(40, 48, 42) = 43	0, 0, 0	84, 55, 87) = 75	0, 59, 54	68, 69, 91) = 76	65, 0, 0	87, 73, 100) = 87
U 4	Ditto, three days standing (damped)	As "K"	3	1	(14, 16, 18) = 16	(18, 19, 20) = 19	(42, 40, 38) = 40	0, 0, 0	64, 61, 72) = 66	48, 0, 0	69, 82, 67) = 73	0, 0, 0	53, 93, 58) = 68
U 8	Ditto, seven days standing (set hard, crushed up, and damped)		3	1	(25, 26, 25) = 25	(40, 26, 20) = 29	(56, 48, 44) = 49	56, 63, 0	73, 80, 112) = 88	0, 0, 111	105, 128, 114) = 116	85, 67, 82	94, 94, 119) = 102
U 11	Ditto, eleven days standing (set hard, crushed up, and damped)		3	1	(12, 16, 18) = 15	(40, 20, 20) = 29	(50, 50, 50) = 50	0, 0, 0	80, 86, 75) = 80	0, 0, 0	102, 74, 74) = 83	0, 75, 69	100, 100, 84) = 95

SERIES V.—RAW MATERIALS.

Laboratory Numbers	Sand	Grading	Volumes of Sand	Lime — Volumes of Un-slaked Lime	Tensile — Fourteen Days	One Month	Three Months	Crushing — Fourteen Days — Spalled	Crushed	One Month — Spalled	Crushed	Three Months — Spalled	Crushed
M	—	—	—	Lime only	(22, 18, 21) = 20	(36, 15*, 12*) = 21	(60, 65, 63) = 63	16, 30, 30	29, 44, 41) = 38	0, 0, 0	56, 40, 53) = 50	66, 89, 86	203, 119, 144) = 155
O	Lewisham Sand No. 1	As "N"	—	—	(under 10, 10, 10) = 10	(10, 8, 8) = 9	(8, 8, 8) = 8	0, 0, 0	21, 20, 20) = 20	(two months) 0, 9, 0	15, 16, 16) = 16	0, 0, 0	21, 17, 16) = 18
Q	Ditto, No. 2	As "P"	—	—	(5, 9, 8) = 8	(12, 8, 11) = 10	(10, 5, —) = 7	0, 0, 0	15, 10, 9) = 14	0, 0, 0	20, 21, 15) = 19	0, 0, 0	20, 6, 12) = 13

* Cracked in setting.

AVERAGE RESULTS.

SERIES I.—VARIANT, FINENESS OF SAND.

Composition of Mortar	Tensile Strength (Lb. per Square Inch)			Crushing Strength (Lb. per Cube Inch)		
	14 days	1 month	3 months	14 days	1 month	3 months
LEIGHTON BUZZARD STANDARD SAND, UNWASHED.						
A. 1 volume sand to 1 volume unslaked lime	26	—	28	99	—	150
B. 2 ,, ,, 1 ,, ,,	31	—	32	97	—	92
C. 3 ,, ,, 1 ,, ,,	—	—	22	—	—	52
D. 4 ,, ,, 1 ,, ,,	—	—	15	—	—	53
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{8}$-inch and retained on $\frac{1}{16}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	—	—	—	87	146	152
2 ,, ,, 1 ,, ,, ,, .	24	35	—	99	74	164
3 ,, ,, 1 ,, ,, ,, .	—	—	—	59	56	86
4 ,, ,, 1 ,, ,, ,, .	22	—	—	46	33	64
5 ,, ,, 1 ,, ,, ,, .	—	—	—	33	34	41
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{16}$-inch and retained on $\frac{1}{32}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	24	39	47	101	127	126
2 ,, ,, 1 ,, ,, ,, .	20	20	27	63	72	104
3 ,, ,, 1 ,, ,, ,, .	27	18	23	55	38	63
4 ,, ,, 1 ,, ,, ,, .	12	19	18	36	35	35
5 ,, ,, 1 ,, ,, ,, .	9	11	9	28	19	27
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{32}$-inch and retained on $\frac{1}{40}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	30	32	43	102	126	104
2 ,, ,, 1 ,, ,, ,, .	23	23	—	64	67	101
3 ,, ,, 1 ,, ,, ,, .	13	16	—	55	64	76
4 ,, ,, 1 ,, ,, ,, .	13	11	—	29	41	33
5 ,, ,, 1 ,, ,, ,, .	8	10	—	31	30	40
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{40}$-inch and retained on $\frac{1}{50}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	17	25	35	57	78	110
2 ,, ,, 1 ,, ,, ,, .	28	28	43	69	47	75
3 ,, ,, 1 ,, ,, ,, .	10	23	27	48	47	60
4 ,, ,, 1 ,, ,, ,, .	6	15	—	31	26	47
5 ,, ,, 1 ,, ,, ,, .	7	10	—	39	30	40
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{50}$-inch and retained on $\frac{1}{75}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	—	—	—	43	68	58
2 ,, ,, 1 ,, ,, ,, .	22	29	—	72	75	66
3 ,, ,, 1 ,, ,, ,, .	—	—	—	48	61	66
4 ,, ,, 1 ,, ,, ,, .	15	14	—	25	33	—
5 ,, ,, 1 ,, ,, ,, .	—	—	—	29	33	—
LEIGHTON BUZZARD SAND, WASHED—Passed $\frac{1}{75}$-inch mesh.						
1 volume sand to 1 volume unslaked lime .	—	—	—	60	67	—
2 ,, ,, 1 ,, ,, ,, .	—	—	—	82	67	—
3 ,, ,, 1 ,, ,, ,, .	—	—	—	25	27	—
4 ,, ,, 1 ,, ,, ,, .	—	—	—	26	18	—
5 ,, ,, 1 ,, ,, ,, .	—	—	—	65	37	—

SERIES II.—VARIANT, CLAY.

Composition of Mortar	Tensile Strength (Lb. per Square Inch)			Crushing Strength (Lb. per Cube Inch)		
	14 days	1 month	3 months	14 days	1 month	3 months

BROWN LEIGHTON BUZZARD SAND.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	30	32	47	116	123	115
2 ,, ,, 1 ,, ,, ,, .	22	25	30	77	80	85
3 ,, ,, 1 ,, ,, ,, .	24	32	31	82	69	78
4 ,, ,, 1 ,, ,, ,, .	26	21	33	58	61	60
5 ,, ,, 1 ,, ,, ,, .	15	16	20	50	42	33

BROWN LEIGHTON BUZZARD SAND—Plus 2½ per cent. clay.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	42	44	88	90	114	140
2 ,, ,, 1 ,, ,, ,, .	20	26	34	98	111	76
3 ,, ,, 1 ,, ,, ,, .	32	29	49	80	108	114
4 ,, ,, 1 ,, ,, ,, .	30	25	46	72	93	90
5 ,, ,, 1 ,, ,, ,, .	30	37	57	66	74	67

LEIGHTON BUZZARD SAND —Plus 5 per cent. clay.   Voids 36 per cent.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	32	48	107	122	158	233
2 ,, ,, 1 ,, ,, ,, .	34	41	85	181	192	217
3 ,, ,, 1 ,, ,, ,, .	31	33	65	111	134	139
4 ,, ,, 1 ,, ,, ,, .	42	47	84	88	133	153
5 ,, ,, 1 ,, ,, ,, .	35	60	74	102	128	108

LEIGHTON BUZZARD SAND—Plus 7½ per cent. clay.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	23	39	65	145	186	192
2 ,, ,, 1 ,, ,, ,, .	32	45	90	93	126	180
3 ,, ,, 1 ,, ,, ,, .	42	55	111	128	174	272
4 ,, ,, 1 ,, ,, ,, .	26	29	72	86	125	122
5 ,, ,, 1 ,, ,, ,, .	38	50	62	118	183	207

LEIGHTON BUZZARD SAND—Plus 10 per cent. clay.   Voids 32½ per cent.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
2 volumes sand to 1 volume unslaked lime .	36	43	85	157	223	261
3 ,, ,, 1 ,, ,, ,, .	31	52	90	163	202	228
4 ,, ,, 1 ,, ,, ,, .	45	44	91	125	181	233
5 ,, ,, 1 ,, ,, ,, .	43	65	88	118	176	234

SERIES III.—LEWISHAM SANDS. VARIANT, CLAY.

LEWISHAM SAND, No. 1—Voids 23 per cent.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	24	23	73	67	94	158
2 ,, ,, 1 ,, ,, ,, .	30	36	90	137	179	+ 233
3 ,, ,, 1 ,, ,, ,, .	32	41	65	86	154	125
4 ,, ,, 1 ,, ,, ,, .	38	43	55	104	157	175
5 ,, ,, 1 ,, ,, ,, .	38	50	58	99	127	131

LEWISHAM SAND, No. 1 (WITH CLAY REMOVED). Voids 34 per cent.

Composition of Mortar	14 days	1 month	3 months	14 days	1 month	3 months
2 volumes sand to 1 volume unslaked lime .	30	30	43	106	91	111
3 ,, ,, 1 ,, ,, ,, .	30	33	59	65	61	87
,, 1 ,, ,, ,, .	18	24	38	35	46	46

SERIES III.—LEWISHAM SANDS. VARIANT, CLAY—*continued.*

COMPOSITION OF MORTAR	TENSILE STRENGTH (Lb. per Square Inch)			CRUSHING STRENGTH (Lb. per Cube Inch)		
	14 days	1 month	3 months	14 days	1 month	3 months

LEWISHAM SAND, No. 2.   VERY RED.   Voids 28·6 per cent.

	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	31	35	83	77	107	206
2 ,, ,, 1 ,, ,, ,, .	25	36	80	78	142	194
3 ,, ,, 1 ,, ,, ,, .	28	32	63	129	155	193
4 ,, ,, 1 ,, ,, ,, .	26	34	48	154	158	138
5 ,, ,, 1 ,, ,, ,, .	27	29	37	97	107	93

LEWISHAM SAND, No. 2 (WITH CLAY REMOVED).   Voids 30 per cent.

	14 days	1 month	3 months	14 days	1 month	3 months
3 volumes sand to 1 volume unslaked lime .	34	36	40	83	88	79

LEWISHAM SAND, No. 3.   FINE WHITE SAND.   Voids 40 per cent.

	14 days	1 month	3 months	14 days	1 month	3 months
1 volume sand to 1 volume unslaked lime .	18	23	82	65	79	126
2 ,, ,, 1 ,, ,, ,, .	25	33	54	124	123	176
3 ,, ,, 1 ,, ,, ,, .	23	28	53	80	70	112
4 ,, ,, 1 ,, ,, ,, .	21	16	45	74	91	106
5 ,, ,, 1 ,, ,, ,, .	19	24	42	71	82	82

SERIES IV.—VARIANT, TIME.

3 VOLUMES LEIGHTON BUZZARD SAND AND 1 VOLUME OF UNSLAKED LIME AND BRIQUETTES AND BLOCKS made up after standing :—

	14 days	1 month	3 months	14 days	1 month	3 months
0 day	14	—	47	75	63	89
1 ,, (no water added)	23	30	45	74	54	97
2 ,, (damped)	23	28	43	75	76	87
3 ,, ...	16	19	40	66	73	68
7 ,, (mortar set hard, crushed up and damped)	25	29	49	88	116	102
11 ,, ,, ,, ,, ,, .	15	29	50	80	83	95

SERIES V.—RAW MATERIALS.

	14 days	1 month	3 months	14 days	1 month	3 months
Lime only	20	21	63	38	50	155
Sand only (Lewisham No. 1)	under 10	9	8	20	{ 2 months 16 }	18
,, (Lewisham No. 2)	8	10	7	14	19	13

*   *   *

The tabulated results of a series of experiments carried out by Messrs. W. Cubitt & Co., to test the strength of Portland Cement Mortars, will appear in the next issue of the JOURNAL, *together with a communication on the subject from Mr. Wm. Dunn [F.]*—ED.

DISCUSSION OF MR. DIBDIN'S PAPER.

The President, Mr. THOMAS E. COLLCUTT, in the Chair.

MR. H. D. SEARLES-WOOD [F.], Hon. Sec. Science Committee and Mortar Sub-Committee, in proposing a vote of thanks to Mr. Dibdin, said that, so far as he had been able to ascertain, there were no published results of experiments upon lime, clay, and sand, although experiments upon cement, clay, and sand had been published. According to the results of the American experiments of the addition of clay to sand, in the case of a one to one mortar, or of neat cements, no improvement had been made to the mortar; but in the mortars of a leaner condition, one to three or one to four, there had been an improvement. But the general result of these experiments seemed to be that it was impossible to say whether clay was or was not beneficial to cement mortar. There was one thing he should like to correct in the Paper. Mr. Dibdin had taken one to three as an absolutely arbitrary proportion. He thought it was the minimum proportion in the By-law—that they would not prosecute for an excess of lime. Turning to Mr. Dibdin's tables, Series 2, Mr. Searles-Wood said that in all diagrams of this sort it was generally allowed that, unless the line given by plotting the result in this way had a fairly regular curve, there must be something exceptional in the results of the experiments. Looking at Series 2, it would be seen that the three to one mixture gave a fairly regular line. But looking at the other series—the two to one or four to one series—it would be seen when they came to $7\frac{1}{2}$ per cent. of added clay that, instead of going in a regular curve, there was a serious drop at that point, and then there was a rise to 10 per cent. He could not help thinking that in that series of experiments there must have been some accidental conditions which had interfered with the results; it was not in the course of nature to have a sudden drop and recovery in that way. He should like to have that result checked in another series. With regard to the question of the admixture of clay with sand, he was glad Mr. Dibdin had laid such special insistence upon the fact that it was pure clay he added, because there was another class of experimenters—the jerry-builders—who had been mixing their mortars with more or less dirty sand for a great many years, and carrying out their experiments in bulk; and they would all agree that the results of those experiments had been disastrous. So that before he could give his adherence to Mr. Dibdin's experiments he should like to see this series of experiments carried a great deal further. Mr. Dibdin had explained to him privately that he did not consider that the addition of clay made any chemical difference to the mortar; that is to say, that no silicate aluminas were formed by the addition

of clay; or if there were any, that they were so infinitesimal that they would not come into account, so that really the only value of the added clay would be to increase the density of that particular mortar and in that way add to its strength. The whole of the results pointed to the value of having varying sizes in the grains of sand, and to the very fine grains being taken out by washing. This was quite in accordance with accepted practice. The ideal mortar consisted of angular grains of silica, each grain entirely enveloped in lime, and the grains thus enveloped being of such varying sizes that they knit into one another and adhered by the crystallisation of the lime between their surfaces, thus forming one homogeneous mass. The rounder the grains of sand and the more uniform their size the smaller were the contact surfaces presented for the lime to crystallise between, until, when the grains approached perfect spheres all one uniform size, the grains only touched at points, and the voids between the grains became either filled with air or uncrystallised lime. Mr. Dibdin's description of measuring the voids in sand was very clear and interesting. It was an extremely difficult thing to gauge accurately what the voids in sand were; but from Mr. Dibdin's description he thought they should all be able to carry out their own experiments on that subject. As regards Mr. Dibdin's suggestion that the By-laws should be drawn with regard to the compressive strength of mortar rather than of proportions, the drawback to that was that it would necessitate a separate experiment every time one questioned the strength of the mortar on a job, and that would mean a delay of at least eight days. Another thing, the specification was naturally a direction to the contractor: the contractor would hand the specification to the foreman, and the foreman would give his instructions from the specification to the particular labourer who had to mix that batch of mortar, and he would not have the slightest idea what was meant if he were told it must have a comprehensive strength of so many pounds to the square inch. It seemed to him that, as the question before them was one which interested them all, it should be an obligation on the part of authorities, such as the London County Council or the borough councils, to instruct chemists like Mr. Dibdin to conduct a series of experiments on the local materials in their particular districts, so that the results should be available to those who came there to carry out building operations. An office should be established in the nature of a bureau of information, and when they wanted to build they should be able to go to this office and ask, for

instance, what was the nature of the local sands. Then they would be given Mr. Dibdin's analyses of the amount of clay in them, and they could get the proportion of lime wanted for it at once. That seemed to him a practical idea which no properly constituted ratepayer could object to the expense of carrying out. In conclusion the speaker said that Mr. William Dunn, who took a great interest in this matter, had handed to him a communication with some very valuable tabulated results. He would not read them to the Meeting, but he hoped they would appear in the JOURNAL in connection with Mr. Dibdin's Paper.*

Mr. WILLIAM WOODWARD [F.], in seconding the vote of thanks, said that Mr. Searles Wood had certainly pointed out additional food for thought; and if he (the speaker) suggested other methods of test with regard to mortar than those enumerated by Mr. Dibdin, he hoped he would clearly understand that his object was not in the slightest degree to diminish the value of what he had told them that evening or of the careful experiments he had made. Again, any proposition which would destroy the cast-iron effect of an Act of Parliament would meet with the recommendation of himself above all others! Therefore, when Mr. Dibdin told them that in place of the hard-and-fast three to one of the by-law of the London County Council, they might speak of five to one; when he told them, as he (Mr. Woodward) had found from his own experience, that the addition of clinkers added to the strength of mortar; and when he told them—and here, again, he thoroughly agreed—that it was not so much the mixture of the mortar that was important as its ability to resist compression: those were matters he thought which would commend themselves to every practical man in the room. The point he wished to bring out with regard to this experiment was this. He sincerely wished that Mr. Dibdin, with his vast experience as a chemist and his great knowledge of the composition of mortar, would substitute real walls for briquettes, which he thought were not sufficiently practical for architects to place implicit reliance upon; they could then find out what the effect on the strength of mortar was with washed sand, and what its effect was with unwashed sand; also to find out the strength of mortar mixed in a pug mill, the strength of mortar mixed with slaked lime, and the strength of mortar mixed with unslaked lime; the effect on the strength of mortar in various thicknesses of joints; any instance of failure in a brick wall through weakness of mortar; the effect of mortar upon various thicknesses of wall; the effect of mortar upon bricks with a "kick" in them, and the effect of mortar upon wire-cut bricks; the effect of frost upon various mortars, and the exact effect of

* Mr. Dunn's communication and the tabulated results referred to will appear in the next issue of the JOURNAL.

mortar used with sand and clay. If they could get experiments of that sort upon walls in place of briquettes, and if they could take notes of the effects of mortars, and of the various ways of mixing mortars, as they found them in their experiences, the results of those experiments would be of more value to them than the results of experiments when tested upon briquettes. He knew the difficulty of doing this; but he believed that every member of the Institute could contribute most valuable information if he would take the trouble in his architectural experience to take notes in the various directions he had suggested.

Mr. MAX CLARKE [F.], Vice-Chairman of the Science Committee and a member of the Sub-Committee on Mortar, said that Mr. Dibdin's Paper seemed to be just what was wanted at the present time. They had been, he supposed from their grandfathers' and great-grandfathers' time, saying that two to one, or three to one, as the proportion of lime and sand, was the right and proper proportion, not knowing exactly why it was so, but simply following that which their ancestors did as being right and proper. He could not help being greatly struck with Mr. Dibdin's results, because just about ten years ago the gentleman who then occupied the Presidential Chair ridiculed the idea of mortar being made up in the proportion of two of sand to one of lime in building the piers which were tested at the West India Docks. Mr. Dibdin's experiments seemed to confirm the proportion of materials adopted on that occasion. He should like to add his quota of thanks to Mr. Dibdin, because this was a matter in which he had taken more or less interest for some considerable time. It appeared to him that the average architect having written the specification remained satisfied without exercising that supervision which was essential for good work. It was one of the essentials, at any rate, that mortar should not be made so hard and stiff as that which the bricklayer was so fond of using. It was also an essential, more particularly with cement work, that the bricks should be properly wet. This consideration, however, was somewhat outside the question. He took it that these experiments were more or less the outcome of a case in the police courts some time ago; and although he was perfectly well aware that Mr. Dibdin had been dipping into the subject very considerably before that case, he knew he had dipped into it now with such effect that the By-laws, in London at any rate, would have to be revised. He was sorry to contradict Mr. Searles-Wood, but it was equally against the law to make mortar in the proportion of two to one, as it was in the proportion of four to one—that had been proved in the courts, and there was now no question at issue upon that point. Another thing which struck him about the tests under consideration, and which consoled him somewhat, was that

they were carried out by one of the most expert chemists of the day—in this land at any rate—and the results showed such remarkable variations that one was naturally led to think that the average material in actual use was very varied, which, of course, was one of the difficulties they had to contend with on the work, as well as in the laboratory. But if there was that variation in laboratory tests carried out with the greatest possible care, what must one expect in a building where no care was exercised at all? For what really did occur? A man absolutely ignorant was set to make mortar. He did the work according to his lights, and the result, of course, was what one might anticipate. He should like to ask what Mr. Dibdin meant by the time of setting. Experts in cement had a recognised method of dealing with what they called "setting"; but it would be interesting to get some definite information from Mr. Dibdin as to what he meant by "setting." Mr. Searles-Wood had said that to ensure the best results one must get a variable size of sand. That, however, was all very well in the laboratory again, where those things could be screened or sifted, and such and such a proportion of one size and such and such a proportion of another size added. By that means one could avoid interstices altogether. But that was an absolute impossibility in the work. Supposing they had, as he had had that very day on one of his buildings, three different consignments of sand. One was extremely coarse, one was a sort of intermediate, and one was extremely fine; and he thought to himself, How nice it would be if he mixed the three samples together, and thus got the use of them all! But he firmly believed that if he had done so, the coarse stuff would allocate one place to itself, and the fine stuff would allocate another place to itself, more particularly if it was done in a mortar mill. That, perhaps, was one of those things one would like to think could be used, but which, he was afraid, upon the work was almost impossible. He would tell them more or less why he considered it impossible. The building he referred to was of a considerable size, and had fire-resisting floors. He had considered the matter of fire-resisting floors very carefully for some time, and had described in his specification that there was to be a certain proportion of broken bricks—broken to a particular size, a certain proportion of coke-breeze, and a certain proportion of sand. He had arrived at the building at about half-past one that day, and found that the man making the concrete had taken upon himself to make it entirely of coke-breeze, because he thought the bricks would be a disadvantage, the coke-breeze being rather large. Now that entailed taking out as much concrete as would cover the area of their present meeting-room, and it would probably entail a loss of £250, which was the bonus to these particular contractors.

If such a thing occurred in a perfectly simple matter, what must one expect in a matter which was more complicated, like dealing with mortar? He thought that, at any rate for the London district, Mr. Dibdin's idea about the way mortar should be tested was a most excellent one, because it was possible in London to know exactly the sort of lime and exactly the sort of sand one was going to use; and, knowing these two, one should know beforehand exactly what the result would be. Therefore the testing would be quite a simple matter. But to go on in the haphazard sort of way that the County Councils and the Urban District Councils would like them to do was quite ridiculous. Many members present were doubtless aware that the Institute had a "Mortar" Committee, of which Mr. Searles-Wood was the indefatigable Secretary. He was sorry the Meeting was so small, but he should like to propose the following resolution : "That this Meeting is of opinion that the question of the composition of mortar is a matter which deserves the fullest consideration, and, with that end in view, the Council be asked to devote a sum of money for further inquiry into the subject." The Meeting that evening had proved to them most completely that it was folly for an architect to try to do this work by himself. He could go a certain way, and could give the result of his experience on the work; but he could not give that absolutely scientific knowledge which was the basis of all things. If they had not got that, they had not even the beginning of the thing, and would never arrive at a definite conclusion; and the Mortar Committee was just in that unhappy state : they had found out a certain amount, and now, without money, they did not know how to find out any more. If the President would put the resolution to the Meeting, and if the Meeting would kindly consider it, the Mortar Committee would be greatly indebted—first to Mr. Dibdin, and then to the Meeting, and thirdly, he hoped, to the Institute.

Mr. ALAN E. MUNBY, M.A.Cantab., F.C.S., Lecturer on the Chemistry of Building Materials to the London County Council, said that the chief difficulty in drawing conclusions from Mr. Dibdin's interesting experiments appeared to lie in the very large number of variable factors which were involved. The initial hardening of mortar depended probably, for the most part, upon : (1) the extent of compression in the mass, such as might be caused by changes of volume produced on solidification; (2) the amount of evaporation which would result in a contraction varying with the nature of the constituents; (3) the solidification attained; (4) the character of the crystallisation, decided by the nature of the crystalline constituents, the quantity of water present, the solubility of the ingredients, their initial temperature, and the thermal disturbance caused by chemical

reactions ; (5) on the time of setting, which put a limit to the motion of the ions in solution. Again, the final strength attained must be governed by the cohesion of the particles, which would, of course, vary with their composition ; and by the area of surfaces of different constituents in contact, their chemical nature, crystalline grouping, and interspaces—in short, by what was called adherence. Was it rational to expect that among such a wealth of variables any scientific results could be drawn directly from experiments which attempted to embrace so many simultaneously? In the first place, we did not even know whether any chemical action took place between the lime and the clay added to the sand. It might seem improbable that clay, the last resisting remnant of disintegrated felspathic rocks, which had, in a minute state of division, been suspended for so long in water (alkaline at least initially), should be soluble enough to react with lime during the short interval before the tests. Nevertheless, some recent experiments on American mortars[*] showed that silica was much more soluble than was generally supposed. One would like to see some experiments undertaken on less ambitious lines to begin with. For example, the clay might be replaced by something entirely above chemical suspicion, such as platinum, in a similar state of division. Again, a further effort might be made to separate chemical and physical effects by initiating experiments on adherence with fat lime mixtures. Briquettes of lime and shot in place of sand might lead to some information as to the effect of configuration and size of particles which would then be under control. Something in the nature of a fat-lime constant for subsequent deduction might possibly result. As to the setting of mortar when re-worked, the supersaturation theory of Le Chatelier and Marignac might provide an explanation. These *savants* have shown that many bodies added in excess to water form supersaturated solutions which deposit crystals after a small interval. As much lime remained unaltered in ordinary mortar, there seemed no reason why, when ground, supersaturation should not again occur on remixing. The subsequent loss of strength after a longer interval might be due to the formation of compounds which would be less soluble than lime, and would consequently produce less concentration in their supersaturated solutions if the rate of setting was not proportionately increased.

Mr. W. D. CARÖE, M.A.Cantab., F.S.A. [*F.*], said that after the very able and scientific remarks they had just heard from Mr. Munby he was afraid his contribution would be of a very banal description. He did not know quite what the orders of the evening were, or whether Mr. Max Clarke's

[*] Headden, *American Journal of Science.*

proposed resolution was in order, and whether it could be seconded ; but this was a subject in which he took an immense interest, and he must say that he felt that there was such a vast amount of knowledge they had yet to acquire on this subject, and that the Institute was of all others the institution which ought to acquire it and lay it before them, that he should like, if it was in order, to second Mr. Max Clarke's proposition that the Institute should take this exceedingly important matter up. For instance, Mr. Dibdin had told them in his very able and interesting Paper all about mortar within a few days, or at any rate within a few months, of its putting together. He should like to know something about that mortar when it had been mixed for five, ten, fifty, or one hundred years. After all, that was what concerned them : it was not what mortar was a few months after it was made—it was what it was going to be when their buildings were handed down to posterity. He happened for a considerable part of his small practice to have to deal with ancient buildings, where he was constantly coming across all sorts of questions in connection with mortar ; and he was bound to say that the conclusions he had arrived at generally might be summed up very shortly : that nearly all the mortar made in the nineteenth century was not to be compared for excellence with the mortar that was made a good many centuries before. He could tell them of many cases where the ancient mortar that was made in the thirteenth and fourteenth centuries, and more especially the mortar that was made in the time of Sir Christopher Wren, was infinitely superior in every way to the mortar that had been used in adding to the buildings during the last century. Why was that so ? Presumably there was more science in the last century ; perhaps there was more jerry-building ; but he fancied the real reason was that the men who made that earlier mortar were definitely trained craftsmen with a tradition, and they had learned locally, where they happened to build, how the sands and limes in that particular district were best put together, with the result that he had tried to describe. He should very much like some experiments to be carried out if it were possible—Mr. Dibdin would tell him if he was wrong—upon the composition of the ancient mortars, to find out how it was that they seemed to have been used—which was an exceedingly important point—without shrinkage. He had more than once made very careful surveys of St. Paul's Cathedral, and the one thing that struck him more than anything else was the fact that Sir Christopher Wren had managed to secure, even for the repair work he had to do, mortars which did not shrink, and which adhered to both sides of a crack. One's experience now of modern mortars, and certainly of modern cements, was that that was a very difficult, and almost impossible, thing to secure. And he had been

immensely struck by that remark of Mr. Dibdin's in which he adumbrated that one of the objections that there might be to the use of clay in connection with sand was the shrinkage which took place in the mortar. That he could certainly, from practical experience, confirm, because he had tried experiments, of no scientific value at all, but simply practical experiments upon that point. Therefore, in joining in this vote of thanks to Mr. Dibdin, he should like to support the resolution Mr. Max Clarke had put before them, that the Institute should go more deeply into this highly interesting and technical matter, which concerned them all so much.

Mr. Max Clarke's resolution was then put to the Meeting and carried.

The President, before putting the vote of thanks, referred to Mr. Caröe's remark that tradition had possibly directed the makers of mortar in the thirteenth and fourteenth centuries and up to the time of Sir Christopher Wren. He himself thoroughly believed that tradition had had a very great deal to do with the superior methods of those days. He had lately been in Spain, and had had occasion during the last few years to see mortar mixed and to have a good deal of mortar used in buildings pass under his inspection. He thought the Spaniards knew a good deal more about the mixing of mortar, especially that used for plastering, than the English did; and he thought that was possibly due to the tradition that had been handed down from the time of the Romans, through the Moors, and again on to the Spaniards. In Spain it was the usual custom to run the stone lime twice through the tubs, and then to mix it with the sand—the sand was not washed in any way, so far as he knew; it was then allowed to remain for at least a fortnight before it was used as a mortar for the building of walls. That was rather contrary to our custom. He should like also, though perhaps it was a little bit outside the scope of the Paper that evening, to say a word about the question of using mortar, or lime, or cement in the way of concrete blocks. He believed that so far as the use of concrete blocks as masonry was concerned it was absolutely a modern way of using it; but on the outskirts of Algeciras, within half a mile of the town, there was a very beautiful aqueduct, built, he believed, by the Moors perhaps some 700 or 800 years ago, though some authorities declared it to have been built by the Spaniards only some 300 or 400 years ago; at any rate there it stood, the most picturesque aqueduct perhaps in the world. An interesting feature about this aqueduct was that the piers were about three feet seven inches square, and on a cursory examination they all appeared to be built of blocks of conglomerate stone. He made some incisions into this, and found that these blocks of what appeared to be conglomerate

stone were actually lime concrete mixed with a local pebble and stones, broken-up stones, with in a few instances bits of mortar in it. Now that lime concrete, built in blocks and built as masonry, had stood, and it was very interesting to consider how well it had stood the weather all these centuries and had answered its purpose. They had listened to Mr. Dibdin with very much pleasure, and he was sure with very great profit, and he put the vote of thanks with all confidence that it would be carried unanimously. [The vote was carried by acclamation.]

Mr. Dibdin, in expressing his acknowledgments, said that the work he had been engaged in had been entirely a labour of love. It was not a new question to him by any means. In his old official capacity he had had to do with mortars and cements in many ways, and in his private capacity he had had great pleasure in following it up; his only regret was that he had not been able to do twenty times as much work. The number of ramifications which showed themselves in every direction as one touched such a comparatively simple question as mortar were surprising. One had only to take a little lime and a little sand and mix them together, and there was mortar. That was true. But when one took different limes and different sands, and when it was remembered that limes varied from almost pure lime (99·9 per cent.) down to limes of 60 per cent. or less, each having its own specific qualities for certain specific work—so that one would do for one thing and would not do for another—one arrived at such a complication that it was almost bewildering to think of the amount of work that would be required to elucidate all the points. The difference between using a grey-stone lime, with a fair percentage of soluble silica, as compared with using fat lime, or blue lias lime, was so very great that it was impossible to put the work forward in the compass of one such paper as this; many papers and many evenings would be required before the problem was solved. He had, in fact, gone into the question as to how many tests would be necessary before one might hope to break the back of the work, and he saw 20,000 in front of him at once; so he decided to manage to do what work he could and attempt the rest in time. Mr. Searles-Wood had picked out one point more particularly, viz. the variable results as given in the diagrams and tables. Mr. Searles-Wood probably had not quite followed his meaning, viz. that the results were necessarily variable. In dealing with laboratory conditions and small quantities of mortar one must of necessity obtain variable results. That was why he was glad that the Institute had printed his results *in extenso*, because they showed the fallacies wherever they existed. They showed the errors that might arise and with what reservations they might accept the results. Averages were an excellent thing in their way,

but in certain cases one had to consider minima. Even with regard to the point mentioned by Mr. Searles-Wood of the $7\frac{1}{2}$ per cent. of clay, the diagram, Series II, showed a considerable drop in one of the factors from 5 per cent., while some of the others went up. That was the case. The curves crossed, and there was obviously, one would say, some error in the experiments. He quite admitted it—they must have it. If they could show him how to make a series of three briquettes with such a thing as mortar, and get absolutely identical results every time, he should only be too delighted to sit at their feet. But his point was this : with the Leighton Buzzard sands as received they got results varying, roughly speaking, about 75 lbs. But the worst result with a $7\frac{1}{2}$ per cent. clay was about 125 lbs., the minima in one case being above the maxima in the other. That showed that there must be something in this difference. Putting the laboratory results on one side, including accidents and all variable conditions, they arrived at that broad differential that they would get double (to say nothing of three and four times) the strength. And when it appeared (as in that series of $7\frac{1}{2}$ per cent.) as if there were some accidental elements in it, it was quite possible that there was. He was prepared to believe that this diagram could not be repeated every time. But when they took 10 per cent. of clay they had overcome that ; they had a minimum of 175 lbs. instead of 75 lbs. ; that had given them a gain of 100 lbs. Variable results did not affect the main facts. The fact remained that there was gradual increment up to that point, and that was a matter, he respectfully submitted, that was worth consideration. As to delay in work by having such a test as he proposed made, he quite admitted that the builder wanted to get on with his work, and could not wait three weeks or a month while somebody was playing about with briquettes. That was not his point. The point was that if they had it fairly established by sufficient experiments that materials which had hitherto been looked upon with suspicion might be passed, any architect or surveyor would say " that is a good material according to my experience, and it may be used," instead of saying, " No, that is a material you must take away—you shall not use it." In certain cases materials would be rejected which would give better results than others which would be accepted, and he suggested that experiments on a working scale should be made to finally establish the facts. As to Mr. Searles-Wood's suggestion that an examination should be made in regard to local material, nothing could be more important or more valuable. It seemed an extraordinary thing that in these days of scientific investigation and exact knowledge, there should be so many loose ideas with regard to the character and effect of using local materials. Why need they go miles and miles away to get something

brought to them, when they had a suitable, or more suitable, material under their feet ? The suggestion adopted by the seconder of the motion as to the investigation of brick walls, he had already dealt with. He had thrown out the suggestion, and he sincerely hoped it would be followed up; because nothing could be more interesting, at least to him, than the experiments the Institute had already conducted on the strength of brick walls. He felt at the time that one factor was wanting, and that although a good deal of work was done upon the composition of the mortar and cement used, yet a good deal more useful work might have been done in connection with the character of mortar. Mr. Max Clarke had spoken of the variations, and rather inferred that there might be objections to hard and fast lines, because one might have variable results with good materials. Exactly so ; but one might have variable results with bad materials. As to the time of setting, his experiments were laboratory experiments, and of course one found a different time of setting with a small quantity on the laboratory table from what would be the case with larger quantities made up in a builder's yard. Probably his data in that matter should be extended to weeks or months. As he had described in the test, the mortar set hard, so that it had to be thoroughly crushed up again in order to get it into the mould ; and in the bulk they would not expect it to set so hard as that in the same time. Mr. Munby's remarks were of extreme interest, and showed an acquaintance with the subject which he hoped to have a better opportunity of discussing with him. The enormous number of variable conditions, as he had already pointed out, were overwhelming ; one wanted a staff of assistants, and little else to do but to carry on these investigations. One must work according to one's means. He had done his best to start the thing so far—at least he knew of no previous work on the same lines; and he hoped that others would assist in elucidating other points which remain unsolved at present. The silica reaction referred to by Mr. Munby was one of those difficult points which required a great deal of investigation ; but he felt that it was altogether too technical a thing, from a chemist's point of view, to impose upon that meeting; because even chemists were not agreed upon the point. It was a fact that chemists were not always agreed amongst themselves ; and this question of the reaction of silica upon lime in mortar was one that required a great deal of work yet. It was intensely interesting ; it brought about all sorts of questions with regard to crystallisation and the behaviour of those crystals one to the other, and the question of saturation and super-saturation and re-saturation and the gradual deposition of crystals one upon the other. For instance, take a super-saturated

solution ; crystals were deposited, and the question arose whether, when deposited under variable temperatures, that water could take up a further quantity and cause a fresh deposit. That was a question they were not in a position to discuss that evening. At the same time he entirely admitted the importance of the question, and he admitted that it was one which required a great deal of work ; but at present he was afraid their information was hardly sufficient to allow them to do more than refer to it. As to experiments with fat lime he had already referred to that. They wanted to work through the whole grading of lime, and to observe it with regard to the sands. There was another point that he might mention with regard to some experiments he had made with cement some time ago with Mr. Grant. They took some sand and found a certain result with cement. The sand was of a peculiar nature. He heated the sand and altered its physical character and used it for making cement briquettes, and they obtained double the strength. There was a slight chemical difference, not much, but a material difference in the physical character, and it resulted in something like double the strength. With regard to Mr. Caröe's question as to old mortar, this had interested him for a long time past ; but he had been in this difficulty. He had tried to get a number of samples of old mortar which could be verified as old mortar, and the approximate date given ; but the difficulty of getting those certificates and statements from an authoritative and skilled person upon whom they could rely seemed to be something enormous. He should personally be very glad if any members of the Institute would kindly send him samples of authenticated old mortar, and he would do his best to make as complete an examination as possible, and summarise the results. It would be of the greatest possible interest to him, and might throw much light upon the whole question. But one might examine a thousand mortars and then find that hardly one of them was authentic. It might be some mortar that was introduced at a later date, and doubts of all kinds might arise. But wherever a sample of mortar could be fairly and properly certified as being of a certain date, he would examine it with the greatest possible pleasure, and he should be grateful for the opportunity. The silica in those old mortars presented a feature of great interest. It was a very difficult subject, because they had silica in new mortar ; but it would be an interesting thing to see how far in an average number of samples (they would want a large average for it) the solubility of silica had increased with age. He was a little sceptical upon the point as to whether that increment in solubility of silica was such a very large quantity after all. But that was one of the points that still required investigation.

9, Conduit Street, London, W., 22*nd Dec.* 1906.

CHRONICLE.

Presentation of Sir Aston Webb's Portrait.

At the General Meeting last Monday, prior to the reading of Mr. Dibdin's Paper, Sir Wm. Emerson [*F.*] rose at the invitation of the President to make the formal presentation to the Institute of the portrait of Sir Aston Webb, R.A. [*President 1902-04*]. The portrait, a masterly work, and a strikingly successful presentment of its subject, was painted by Mr. Solomon J. Solomon, R.A. [*H.A.*], and hung in this year's exhibition at the Royal Academy. The commission was undertaken by Mr. Solomon for members subscribing to the Portrait Fund, and Sir Wm. Emerson acted as their spokesman in making the presentation to the Institute. The following is a note of the remarks on the occasion :—

Sir WILLIAM EMERSON said it was his pleasurable duty on behalf of the subscribers to ask the Institute's acceptance of the portrait of their Past President, Sir Aston Webb. He much appreciated the task that had been imposed upon him, for it gave him the greatest pleasure to say a few words concerning his friend, the subject of the portrait. Sir Aston's activities were known to all of them, and nothing he (Sir William) could say would be new. Their Past President commenced many years ago by taking an interest in the Architectural Association, and his various activities in connection with that body ended by his being made its President. He then became a member of the Council of the Institute, was afterwards Honorary Secretary, and finally occupied the Presidential chair. During nearly the whole period of Sir Aston's connection with the Institute Council, he (Sir William) had had the pleasure of working with him. He could testify to the marked ability Sir Aston brought to bear on every question that came before the Council, to his unvarying courtesy, his thoughtful consideration of every detail, his unfailing tact, and his rare judgment and sagacity in all questions the Council had had to consider. They all knew what a successful term Sir Aston's Presidency had been. But his activities had not been with the architectural bodies alone. He had

been elected A.R.A., and shortly after, with a very much briefer interval than was usually the case, he was elected to the full rank of R.A. At the Academy, he believed, his activities were as great, if indeed they did not exceed, those he had displayed in the concerns of the Institute. As regards Sir Aston's architectural works, it seemed almost superfluous to speak of them, but he should like to refer to two or three of his buildings. The large hall, for instance, of the Law Courts at Birmingham, which was magnificent in its proportions, and beautiful in its detail, he thought was as successful a modern work as any that could be pointed to. The charming Life Assurance Office in Moorgate Street, with its studied and picturesque beauty of detail, was worthy the admiration of all. Then, again, the Victoria and Albert Museum, now gradually becoming disclosed as the scaffolding was removed, with its charming arcading, and the central feature, which bade fair to be a unique landmark in London. He would also mention the Royal College of Science, the new Christ's Hospital Schools, the Birmingham University, and finally the Queen Victoria Memorial, in connection with which Sir Aston was responsible for the laying-out of the fine processional road, and for the surroundings to Mr. Brock's beautiful design for the monument itself. All of these were works of a monumental character, and worthy of their greatest admiration. Sir Aston Webb's career had been a lesson to all of them, especially as regards his capacity for hard work and his unflagging perseverance and industry. The graceful courtesy with which he always met them at their various functions, business and social, his constant kindliness to the junior members of the profession, and his genial fellowship had won him a place in their affections from which he would never be dismissed.—In conclusion Sir Wm. Emerson unveiled the portrait and asked the Institute's acceptance of it on behalf of the subscribers.

THE PRESIDENT said it was a great privilege, and a great pleasure, to occupy the Chair on such an occasion, and to be the recipient on behalf of the Institute of so great a work of art, and it was an added pleasure when this work of art represented one of their most gifted and most distinguished Past Presidents. They all knew Sir Aston Webb's great talents and his distinguished career, but he should like to add that to all those who knew him there was something beyond even his great talents and his great career —there was the personality of the man himself. He could only regard Sir Aston Webb as an old friend, as a man who inspired with affection all those who had to deal with him. He quite endorsed every word Sir William had said with regard to their dear friend and Past President, Sir Aston Webb, and he was sure he had only to put it to the Meeting and they would receive this very valuable and beautiful work of art, his portrait,

with acclamation. He should like to add that he had received a letter from Sir Aston Webb in which he expressed his regret that he should be unable to attend their meeting that evening. The letter went on : "I must say to you how much I appreciate the compliment (which the fact that it is a usual one to Past Presidents in no way diminishes) that my portrait should hang in such distinguished company on the walls of the Institute Meeting Room, where I have spent so much time, sometimes in friendly conference, sometimes in friendly combat, but always enjoyably, and my only regret is that I have reached the stage when I must leave the arena, make my bow, and hang lifeless upon its walls. It is the fate of all, and quite right that it should be so, and from our place of vantage on its walls I trust and believe we shall watch fresh and vigorous generations carrying on the work of the Institute with ever-increasing success—not weakly giving in to the clamour of every passing whim, but wisely steering a middle course with justice and foresight. Perhaps I may be allowed to say how admirably I think Solomon has justified his task, and the obligation I feel under to him. . . . I merely write this to assure you and the members of the Institute that I am not unmindful but very grateful for this, the last of many honours they have been pleased to confer on me ; and for these and many other benefits I shall always feel deeply indebted."

The New County Hall Competition.

Some recommendations of the Establishment Committee of the London County Council in the matter of the proposed County Hall Competition have been made public during the past week, but the scheme has still to come up for the consideration of the general body of the Council, and it may be some weeks before the conditions are definitively arranged. The competition is to be in two stages, a preliminary and a final, there being two assessors in the former (Mr. Norman Shaw and Mr. W. E. Riley, the Council's architect) and three assessors in the latter—Mr. Shaw, Mr. Riley, and a third assessor to be selected by the competitors in the final competition. The cost of the building is put at £850,000. The Establishment Committee recommend that the following eight architects be invited to submit designs in the final competition :—Mr. John Belcher, Mr. William Flockhart, Mr. Ernest George, Mr. Henry T. Hare, Mr. T. G. Jackson, Mr. E. L. Lutyens, Mr. E. W. Mountford, and Messrs. Nicholson and Corlette. The competitors in the final competition will receive 200 guineas each. The successful architect would be assigned the work of carrying out the design in conjunction with the Council's architect, the successful architect receiving nine-tenths of the usual commission of 5 per cent. and the Council's architect receiving the remaining one-tenth.

The date for sending in designs for the preliminary competition is recommended to be 7th May next, and for the final competition 3rd October following. In the preliminary competition it is recommended that the assessors select in private not fewer than ten nor more than fifteen designs, the authors of these to compete with the eight selected architects in the final competition. Mr. Riley is to have discretionary power in all matters relating to internal economy, building construction, and stability.

An official copy of the proposals of the Establishment Committee may be seen in the Institute Library, but attention is called to the fact that these proposals are liable to extensive revision when the matter comes before the County Council.

The Codification of Water Regulations.

At the meeting of the Joint Committee on Water Regulations held at the Guildhall a few days ago, representatives of authorities and companies attended from Birkenhead, Bradford, Birmingham, Bury, Hull, Preston, Newcastle, Weardale, South Staffordshire, Stockport, South Hants, and the Metropolitan Water Board.

Mr. W. D. Caröe [*F.*], Master of the Plumbers' Company, was voted to the Chair in the absence of Dr. Crawford, Chairman of the Committee.

In opening the proceedings, Mr. Caröe said that if the Chairman had been present he would, no doubt, have remarked on the work of the Committee from the point of view of the Public Health Administrator and Water Authority. He himself regarded the matter rather from the point of view of the architect and consumer. From his own experience he found the greatest difficulty in dealing with the large number of varying regulations, and the Council of the R.I.B.A. would warmly welcome the codifying of water regulations, and the setting up of such standards for fittings as would represent, at any rate, an irreducible minimum of efficiency.

Mr. E. Antony Lees (Birmingham) presented the Report of the General Purposes Committee, together with a Draft Annotated Model Code of Regulations, with schedules attached setting out the specifications of water fittings, &c., compiled from reports of the various sub-committees, and prepared in form for publication.

On the motion of Mr. J. Watson (Bradford), seconded by Mr. Bancroft (Hull), the General Purposes Committee were empowered to conduct the necessary negotiations with the Local Government Board, with a view to the inclusion of the Draft Code framed by the Committee, in the Model Series of Regulations issued by the Board, for the purpose of local Acts and Provisional Orders, enabling Regulations to be made on the subject of the Prevention of Waste or Contamination.

Mr. W. D. Caröe [*F.*] and Mr. Fitzroy Doll [*F.*] were added as members of the General Purposes Committee.

Appointments, &c.

Professor W. R. LETHABY, F.S.A. [*F.*], has been appointed Surveyor of the Fabric of Westminster Abbey.

Sir ASTON WEBB, R.A. [*F.*], has been re-appointed representative of the R.I.B.A. on the Court of Governors of the University of Sheffield.

Sir ASTON WEBB has accepted the invitation of the Council to represent the R.I.B.A. at the celebration at Washington, on the 8th January, of the Fiftieth Anniversary of the foundation of the American Institute of Architects. Sir Aston leaves for America on the 22nd inst.

The Joint Reinforced Concrete Committee have had placed at their disposal the General Meeting of the 27th May, when they will be in a position to report upon the various subjects of their inquiry [see JOURNAL, 28 Apr. 1906, p. 338 ; 8 Dec. p. 96].

The late Henry Allen Prothero [*F.*].

Mr. Henry A. Prothero, of Cheltenham [*Fellow*, elected 1896], whose death occurred on the 25th ult., was born in 1848, and was educated at Cheltenham College (where he was Classical Medallist) and at Balliol, taking his M.A. degree in 1871. He was articled to the late Mr. John Middleton, and was afterwards associated in partnership with him, together with the late Professor J. H. Middleton and Mr. G. H. Phillot, the firm practising at Westminster, Newport, and Cheltenham. The most considerable monument to his talent is Cheltenham College Chapel, one of the comparatively few vaulted buildings erected in modern times, and recently enriched with reredos, organ, and carved stalls, in accordance with the original design. From 1886 to 1895 he was architect to the Ladies' College, Cheltenham. The alterations at Christ Church, Cheltenham, were carried out from his designs ; and there are examples of his work at All Saints' and many other churches in and near Cheltenham. He was responsible for new churches at Leeds, Aberystwith, Carmarthen, Coeth Poeth, and Manordeifi ; and he carried out a very large number of restoration schemes all over the country. In Cheltenham he designed the Delancey Hospital and the Children's Home. Other works include the Canterbury wing of St. David's College, Lampeter, St. Saviour's Homes, Hendon, Goodrich Castle, Ross, besides a large number of schools, vicarages, &c. Mr. Prothero was an ardent antiquarian, was a member of the Gloucestershire Education Committee, and took an active part in the University Extension movement in the district.

The late William Mackison [*F.*].

Mr. William Mackison, who has just died at the age of seventy-three, was elected Fellow of the Institute in 1865. He was a native of Stirling, and was educated in the High School of

Dundee. Having in view the law as a profession, he was first placed with a firm of solicitors, but left them shortly afterwards to enter the office of his uncle, the late Mr. Francis Mackison, architect of Stirling, when he decided to adopt the architectural profession. Mr. Mackison had a successful career at Stirling, many important buildings, residences and others, being erected to his designs in Stirling and the surrounding district. He held the offices of master of works, burgh surveyor, and town architect. The excavations at Cambuskenneth Abbey and the restoration of the fine old tower of the Abbey were carried out under his supervision. It was in recognition of this work that he was elected a Fellow of the Scottish Society of Antiquaries. In 1868 Mr. Mackison went to Dundee as Burgh Surveyor. Among his first works in his new post was the laying-out of the grounds around the Albert Institute, the formation of Balgay Hill and cemetery, and extensive works in connection with the Police and Improvement Act of 1871. The public baths, public cattle-market and abattoirs, the police stations and extensions, various hospitals, cleansing department buildings, skating-ponds, fish-market, &c., were designed and carried out under his directions. He prepared the Parliamentary plans for the street tramways, the esplanade, and river reclamation works, the Parliamentary plans for the boundary extension, &c. He also acted for a time as water manager. During the water famine he brought the water of the Fithie into the Crombie Reservoir, carried out considerable extension of town piping, and effected many improvements at Monikie. Mr. Mackison helped to found the Dundee Institute of Architects, was its first vice-President, and afterwards President.

MINUTES. IV.

At the Fourth General Meeting (Ordinary) of the Session 1906-07, held Monday, 17th December 1906, at 8 p.m.—Present: The President, Mr. Thos. E. Collcutt, in the Chair; 26 Fellows (including 7 members of the Council), 31 Associates, and visitors: the Minutes of the Meeting held 3rd December 1906 [p. 98] were taken as read and signed as correct.

The following members attending for the first time since their election were formally admitted by the Chairman, and signed the Register—viz. Claude Harrison, *Fellow*; Ernest Thomas Jago, *Associate*.

The following candidates, found by the Council to be eligible and qualified according to the Charter and By-laws, were nominated for election:—As FELLOWS (2): Charles Sydney Spooner; Thomas Harry Weston [*A.* 1895], Bristol. As ASSOCIATES (2): Matthew James Dawson [*Probationer* 1900, *Student* 1905, *Qualified for Assoc.* 1906]; Harry George Leslie, F.S.I. [*Special Examination*]. As HON. CORRESPONDING MEMBERS (16): Robert Böker (Member of the Imperial Society of Russian Architects), St. Petersburg; Louis Bonnier, President of the Société des Architectes diplômés par le Gouvernement

Français, Architecte-en-Chef des Bâtiments Civils et Palais Nationaux (Paris); Frank Miles Day, President of the American Institute of Architects, Lecturer on Architecture at Harvard University, Philadelphia, U.S.A.; Jean-Joseph Caluwaers (Brussels); Mariano Eduardo Cannizzaro (Rome); Cass Gilbert, Vice-President American Institute of Architects (New York, U.S.A.); Georges Harmand, Avocat à la Cour d'Appel, Paris, Member of the Judicial Council of the Société Centrale des Architectes Français, Member of the Committee of Historic and Scientific Works at the Ministry of Public Instruction (Paris); Hermann Helmer, K.K. Oberbaurath (Vienna); Virgil Nagy, Building Councillor to the Kingdom of Hungary, Professor at the Hungarian Technical University (Budapest); Ludwig Neher (Frankfort-on-Main); George B. Post, Past President of the American Institute of Architects, Chevalier of the Légion d'Honneur (New York, U.S.A.); Jacques Maurice Poupinel, Architecte diplômé par le Gouvernement Français (Paris); Abraham Salm G.B.zn. (Amsterdam); Ventura Terra (Lisbon); Don Fernando Arbós y Tremanti, Member of the Spanish Academy of Fine Arts, Inspector-General of Works at the Ministry of Fine Arts, Madrid; Gustaf Wickman (Stockholm).

Sir William Emerson, *Past President*, having addressed the Meeting with reference to the professional career and work of Sir Aston Webb, R.A. [*Past President* and *Royal Gold Medallist*], unveiled, and, on behalf of the subscribers, presented to the Institute, the portrait of Sir Aston, painted by Mr. Solomon J. Solomon, R.A. [*H.A.*]. The President, having responded and accepted the gift on behalf of the Institute, read some extracts from a letter he had received from Sir Aston Webb with reference to the presentation.

Mr. W. J. Dibdin, F.I.C., F.C.S., read a Paper on THE STRENGTH AND COMPOSITION OF MORTAR, upon which a discussion ensued, and the proposition having been moved by Mr. Max Clarke [*F.*], and seconded by Mr. W. D. Caröe, M.A., F.S.A. [*F.*], it was

> RESOLVED, That this Meeting is of opinion that the question of the composition of mortar is a matter which deserves the fullest consideration, and with that end in view the Council be asked to devote a sum of money for further inquiry into the subject.

A vote of thanks to Mr. Dibdin for his Paper, moved by Mr. H. D. Searles-Wood [*F.*], and seconded by Mr. Wm. Woodward [*F.*], was carried by acclamation.

Mr. Dibdin, having responded to the vote of thanks, replied to various points raised in the discussion.

Mr. William Woodward [*F.*] gave notice that at the next meeting he would call attention to the terms of the competition for the new County Hall.

The proceedings then closed, and the Meeting separated at 10 p.m.

Discussion of 3rd December: A Correction.

Mr. W. J. Gilliland [*F.*], of Belfast, who took part in the discussion on the Fellowship Question at the Meeting of the 3rd December, points out that the concluding remarks reported at the end of Mr. Maurice B. Adams's speech (JOURNAL, p. 89)—viz. "There was another matter" down to "on the occasion referred to"—were uttered by himself (Mr. Gilliland), not by Mr. Adams, as reported. Further, the amendment which immediately followed, and which failed for want of a seconder, was not Mr. Gilliland's proposal, but another member's, whose name was missed by the reporter.

8

HÔTEL DE VILLE NEUILLY-SUR-SEINE, PARIS: VESTIBULE.

MODERN TOWN-HALLS OF FRANCE: THEIR PLANNING, DECORATION, AND EQUIPMENT.

[From the Godwin Bursary Report 1905.]

By FREDK. R. HIORNS [A.], *Godwin Bursar* 1905.

PART II.—TWO TYPICAL "MAIRIES" OF PARIS.

HAVING dealt with the Hôtel de Ville of Paris, which is a building of a special type and importance, it might be well to mention what appear to be the more prominent characteristics of the average modern " mairie," viz. :—

(1) An imposing principal entrance, with vestibule, hall, and staircase leading to a suite of reception-rooms, usually on the first floor, comprising the Salles and Salons des Fêtes. These are used for civic receptions, and with their approach form the most noteworthy features of the building.

(2) Next in importance is the Salle des Mariages, with its ante-rooms, usually placed on the same floor as the Salles des Fêtes, and frequently more or less *en suite* with them. The Mayor's apartments usually adjoin the Salle des Mariages.

(3) A municipal council chamber, also, as a rule, on the first floor, which, in addition to the seating for councillors and the mayoral " tribune," has accommodation for the public and the Press, as is customary in this country. An ante-room, a robing-room, one or two committee rooms, lavatories, &c., are the usual adjuncts.

(4) The Court of the Justice of the Peace, for the trial of petty offences, and usually
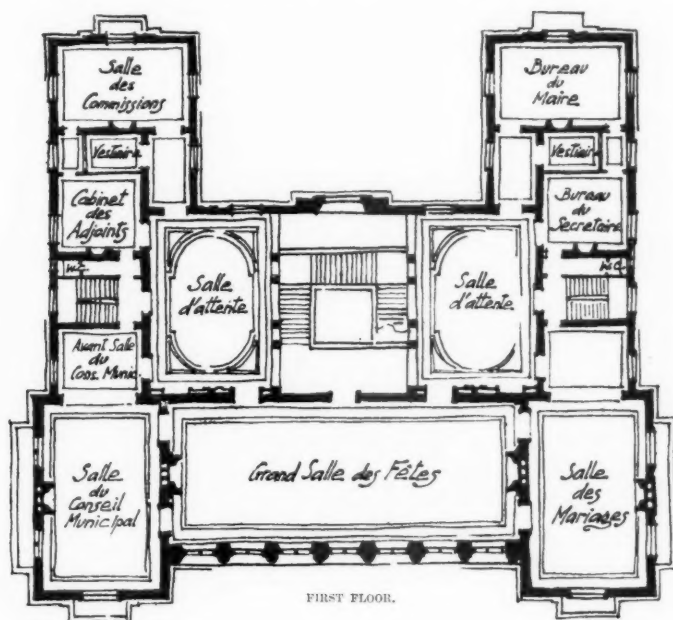
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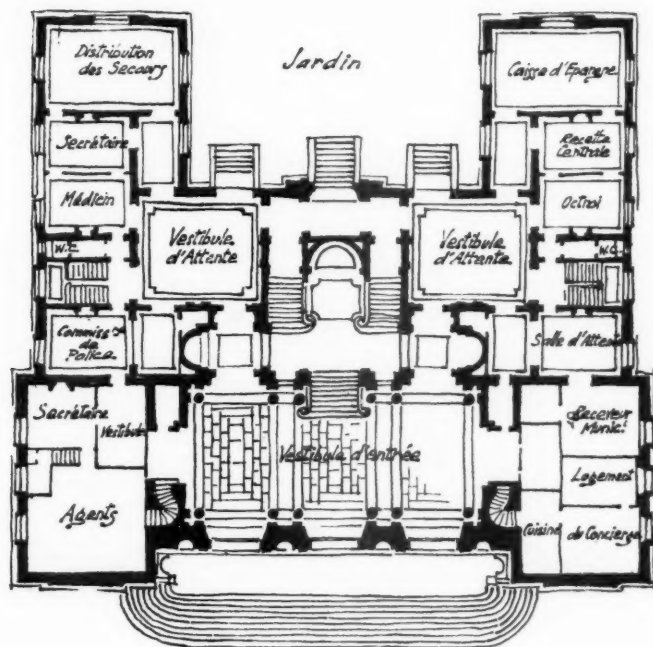
GROUND FLOOR.

THE HÔTEL DE VILLE, NEUILLY-SUR-SEINE, PARIS.

placed on the ground floor, with Judges' apartments and Police Department in proximity. A special entrance from the street is usually provided.

(5) On the ground floor, also, a Salle de Réunions, or small public hall, is commonly found, used for concerts, lectures, &c., for the benefit and pleasure of the inhabitants. This should have a special entrance also.

The principal rooms being of considerable size and height, it is common to find the portions of the building occupied by the subsidiary administrative offices, &c., arranged with intermediate or mezzanine floors—a convenient and economical arrangement. The offices provide for the Secrétaire-Général and his staff, Public Works Department, registrars of births, deaths, and marriages, building inspectors, poor relief, &c., and concierge.

There are special staircases to serve these offices, the principal staircase being reserved for ceremonial occasions and important marriages.

THE HÔTEL DE VILLE, NEUILLY (PARIS).

The township of Neuilly-sur-Seine lies just outside the fortifications, on the west side of Paris. It was once a hamlet in the midst of a forest, of which only the Bois de Boulogne now remains. Its municipal council was constituted in 1790. Thanks largely to the magnificent roads that link her directly to Paris, Neuilly has become one of the most beautiful quarters of the capital, with numerous fine and stately buildings. The accommodation for the Municipality provided in the old "Mairie" eventually becoming inadequate and unsuited to the increasing population, a new building to replace it was projected in 1879. In the architectural competition for the building of a new Hotel de Ville which followed, M. André, of Lyons, gained the first place out of sixty competitors. M. André, however, through pressure of other work, was unable to undertake so important a commission, and it was eventually entrusted to MM. Dutocq and Simonet, architects of Neuilly, who were also premiated competitors. It was stipulated that M. André's façade should be retained, though some modifications even in this were afterwards made, and various adjustments and alterations in the size and planning of the building consequent on more careful consideration of the problem and a reduction of the proposed expenditure. Much credit is no doubt due to MM. Dutocq and Simonet for the excellent building resulting from their skilful execution of the task entrusted to them. The new building was commenced in 1882 and completed at the end of 1885.

The plan is rectangular and symmetrical, with side wings projecting at the back, beyond which is a small public garden attaching to the building. The building is open all round, and the roads adjoining are wide. The principal front faces the Rue de Roule, and has a length of 40 metres. In the centre are three arched doorways, reached by a flight of steps, extending the whole length of the central portion of the façade, which lead into the large entrance vestibule. Off the centre of the long internal side opposite is the grand staircase leading to the ceremonial and reception rooms on the first floor—Salles des Fêtes, Mariages, Conseil Municipal, &c. Conveniently planned near to the Salle des Mariages are the apartments of the Mayor.

From the secondary vestibules at the sides of the main staircase, and which are used in connection with the administrative entrances at the back of the building, there lead the two service staircases of the offices. The building has two principal floors—the ground and the first floor—and also a basement, mezzanine floor, and some rooms in the roof. The plans explain the accommodation provided on the two principal floors, and the section their form and arrangement. On the mezzanine floor, between ground and first floors, are the offices of the Secrétaire-Général, Public Ways and Sewers, the town architect, and the registrars of births, deaths, and marriages. In the basement are installed the heating boilers and

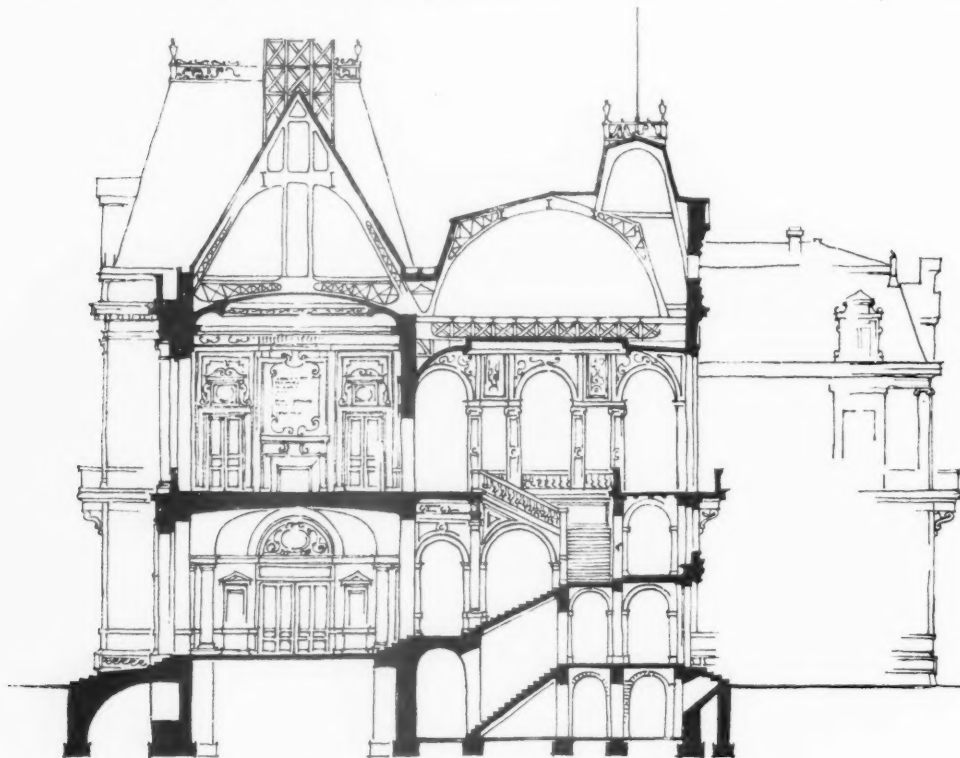HÔTEL DE VILLE, NEUILLY-SUR-SEINE, PARIS (M. DUTOCQ AND SIMONET, ARCHITECTS).

the apparatus for introducing warm air to the principal rooms above; also an "archives" store, general store, and a few prison cells.

The building has concrete foundations on a soil of chalky sand. The basement walls and external walling generally are in "meulières" stone, laid in hydraulic lime mortar (Beffes), with superior stone facings where required. The latter include Ravières, a specially hard variety of stone used for plinths, columns, arches, abutments, &c., "banc royal de Méry" and "Marly" stone for the bulk of facing in the principal façades. The upper stage of the exterior, including dormers, clock pediment, chimneys, &c., is in "Parmain," which appears specially suited for fine carving. In the interior the main division walls are of rubble masonry in hydraulic mortar, with the thinner partitions in brick. The internal facing of the ground and

first-floor vestibules and principal staircase appears to be mainly of "Parmain" stone, the steps themselves being in white "échaillon," and the staircase handrails, about a foot in width, of a fine, hard, polished plaster similar to Parian.

The floors generally are of concrete and iron joist construction, with vaulting of bricks or fireclay blocks. The floors of the Staircase Hall and Salles d'Attente are paved with stone and mosaic.

The mansard roofs are mainly of iron construction (see section), uprights, purlins, and cross-ties and bracing, with wood slating battens on to which the slates are wired. The

THE HÔTEL DE VILLE, NEUILLY-SUR-SEINE, PARIS ; SECTION AT RIGHT ANGLES TO PRINCIPAL FAÇADE.

"flèche" (43 metres high above ground) is also of iron framing, carried on two plate girders a metre in depth, with a circular staircase for access to the outside galleries, from which fine views over Paris are obtainable. The roofs are covered with "Angers" slates, and the gutters and ornamental flashings and other embellishments are of lead and zinc.

The two smaller staircases are formed with H-iron strings, plate iron risers, and stone treads, supported on small angle irons riveted to strings and risers.

The building is heated by warmed air supplied from the two basement heaters. The larger apartments have openings in the ceiling above the electroliers for the escape of vitiated air.

The building is designed in the style characteristic of the later French Renaissance, with refined detail, and will probably be conceded a well-proportioned and elegant example of

the phase of architecture which it illustrates. The sculpture is by MM. Tony Noel, Barrias, Gaud, and others.

The recumbent figures at the base of the masonry setting of the clock represent the "Duties" and "Rights" of man, the supporting female figures "Day" and "Night," while infants at the apex hold a cartouche inscribed with the name of the town.

The sculptured frieze of the external Corinthian order and the panels at the base of the projecting front pavilions are noteworthy pieces of work.

The garden square at the back of the building is a pleasing feature in the *ensemble*, and is open at certain hours for the use of the inhabitants.

The cost of the building was 1,500,000 francs (about 1,220 francs per square metre), and about 180,000 francs has so far been spent on painted decorations and sculpture. The cost of

NEUILLY-SUR-SEINE. — *Escalier de l'Hôtel de Ville*   N.D Phot:

HÔTEL DE VILLE, NEUILLY-SUR-SEINE, PARIS : STAIRCASE.

the steel constructive work was 152,500 francs, and of the ornamental ironwork 26,000 francs, or over £1,000, while the lustre lamps absorbed an almost equal amount—25,000 francs.

From a decorative standpoint the building is as yet incomplete, and paintings and mosaic intended for the embellishment of its walls and ceilings have been carried out to a small extent only. Some internal sculpture groups, of which there are several in the vestibule and staircase hall, exist at present in the form of plaster models only.

The central panel of the ceiling above the main staircase has already received a painting, and also the internal side wall of the Salle des Fêtes. This latter apartment, the decorative treatment of which is in the style associated with Henri II., is of elegant proportions and delicate colouring in buff and gold. The paintings above the dado of the side wall illustrate scenes in French history. The large lunettes above the marble chimney-pieces at each end

of the room are intended to receive paintings or tapestries, with sculpture at the base supported on the projecting chimney-breasts.   The ceiling is deeply coffered and enriched.   The floor is of polished oak blocks, and the furniture upholstered in a material of an electric blue colour. Although at present in an unfinished state, over £1,000 has already been spent in the decoration of this room.

The other rooms are of some interest, but unfinished : the Municipal Council Chamber at the date of my visit was undergoing alterations, and was in a state of complete disorder.

The sizes of some of the principal apartments are as follows :—

Entrance Vestibule	. .	18·50 metres by 9 metres by 7·50 metres high (60½ feet by 29¼ feet by 24½ feet high).
Salle des Fêtes	. .	22 metres by 9 metres by 8·70 metres high (72 feet by 29¼ feet by 28¼ feet high).
Salle des Mariages	. .	12 metres by 7·50 metres by 8·70 metres high (39 feet by 24½ feet by 28¼ feet high).
Salle du Conseil Municipal	.	Do. Do. Do.

THE MAIRIE DU Xème ARRONDISSEMENT, PARIS.

An architectural competition took place in 1889 for designs for this building, the first place being won by M. Eugène Rouyer, a distinguished French architect, who in the year 1873 had taken second place in the competition for the Hôtel de Ville of Paris.   The new Mairie has been carried out from M. Rouyer's designs and under his direction, with M. René Dulong, architect, as his principal inspector.   M. Rouyer died in 1901, only a few years after the completion of the structure.

Broadly speaking, the building is planned on four sides of a square, with a large central court or hall, the full height of the building being covered by a glass roof springing from the low "order" around the top story.   This central space forms the reception hall, from which the principal staircase leads to the Salle des Fêtes, and, by means of the circumscribing galleries, to the Salle des Mariages, &c.

The size of the central hall is 20·10 metres by 12·66 metres (66 feet by 41½ feet), and it is arcaded at the sides from the ground floor to the first-floor level, and colonnaded from the first floor to the second, with galleries round at both these stages.   This is explained by the section through the building showing the interior of the hall.   The height to the lantern is about 20·50 metres, or 67 feet.   The floor is of mosaic.

A sort of ante-hall occurs between the great hall and the entrance vestibule, which the irregularities of the site necessitated being placed at an angle with the main axial line.   A point worthy of note is the skilful way in which the junction between these two apartments is planned.   The vestibule itself (21·90 metres by 8·40 metres by 7·56 metres high) is reached from the road by five openings 2·50 metres in width, filled with metal grilles of beautiful design and workmanship, having steps leading up thereto from the road.   Beyond are others between the vestibule and the ante-hall.

The administrative offices are placed along the two sides facing the Rue du Château d'Eau and Rue Hittorf, and have mezzanine floors and service staircases opening off the ante-hall.
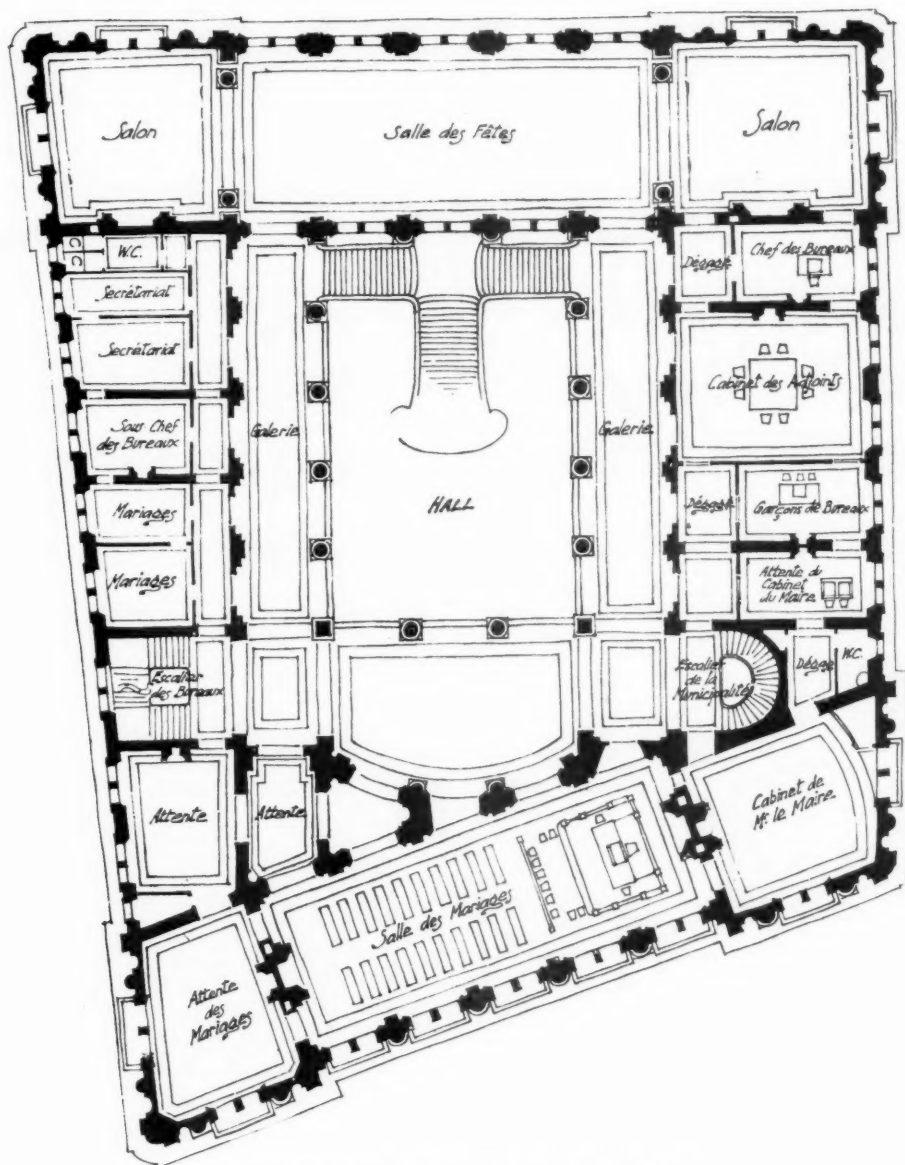
The principal staircase is about 3·20 metres in width and of stone, but with this exception practically the whole of what appears to be stone facing throughout the vestibule and central

Salle
des
Mariages

Grand
Vestibule
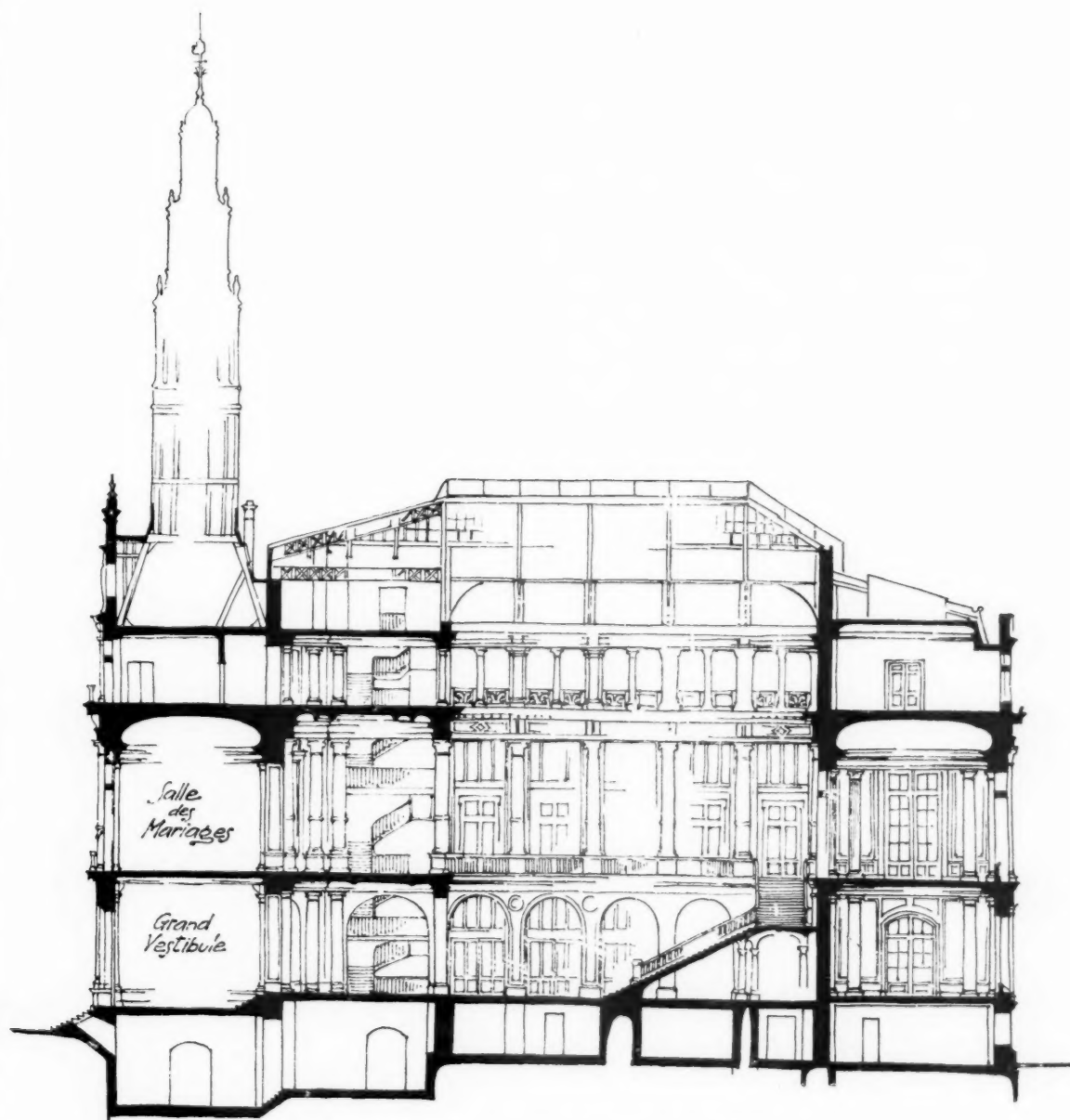
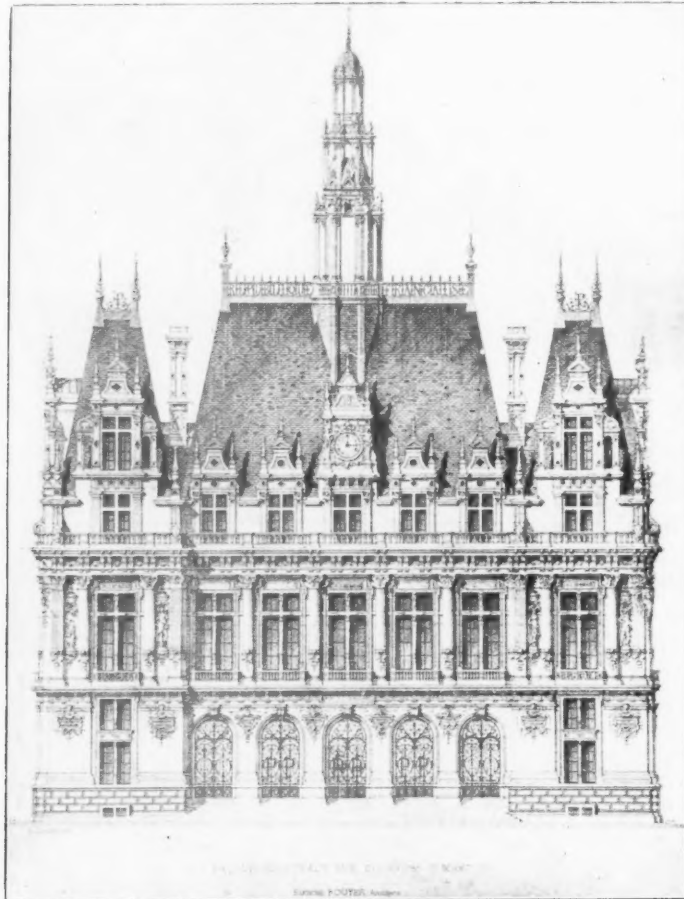MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS: LONGITUDINAL SECTION.

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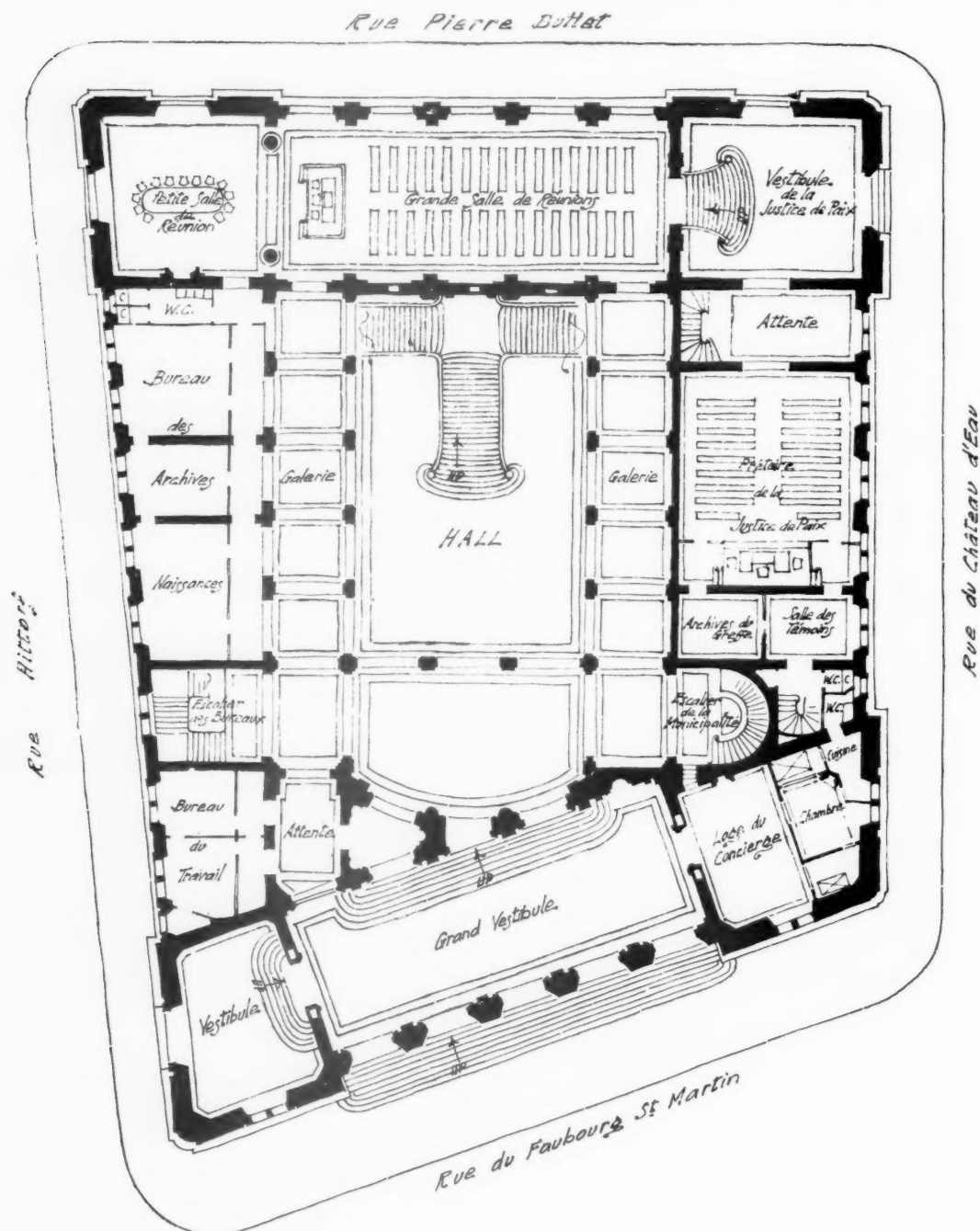
MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS: GROUND-FLOOR PLAN.

MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS: FIRST-FLOOR PLAN

hall is stucco plaster blocks, unfortunately of such a soft character as to be already badly chipped and damaged. The whole is uncoloured. On the wall above the intermediate landing of the staircase is a tablet in polished red marble recording the inauguration of the building in 1896.

The Salle des Fêtes (including the end salons) is 42·50 metres long (139 feet), 9 metres

MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS : PRINCIPAL FAÇADE.

wide (29½ feet) by the same dimension in height. The colour decorations are in a greyish buff and gold, but look old and neglected; in fact, the whole building suffers from neglect and disrepair, resulting apparently from lack of the funds necessary to do what is required. The execution of various paintings proposed for the decoration of this room has not yet been attempted, and the same remark applies to the other principal apartments.

The floor is of hardwood parquetry. The ceiling is partly flat and plain, with large coves above the cornice, around which electric lamps are ranged at intervals. On the pilasters

ranging round the walls of the room are electric lamp brackets, and there are pendant electroliers in the centre of the salons.

The fireplaces are not yet formed.

The Salle des Mariages (21·90 metres by 8·40 metres by 9 metres in height) has a

METAL GRILLE TO ENTRANCE DOORWAYS, MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS.

similar general treatment to that last described, and the same evidence of neglect. The furniture, however, is of mahogany, beautifully carved and upholstered in red velvet. There are two steps up to the daïs, and three to the Mayor's chair. The fireplaces here also are not completed, the spaces where they are to occur being covered with wood casings and hangings. The floor is of polished hardwood as before. The windows are glazed with tinted and leaded glass.

The Salle de Réunions and Court of the Justice of the Peace have a common entrance and a vestibule. The dimensions of these two apartments are 21·75 metres by 9 metres by 6 metres, and 11·75 metres by 9·75 metres by 8·50 metres respectively, but they are of no special architectural interest.

The heights of the principal floors of the building are :—

From ground to first floor . . . 6·59 metres
From first to second floor . . . 9·37 metres
Third floor . . . . . about 4 metres

The exterior of the building is faced entirely with stone, and designed in the style of a somewhat florid period of the French Renaissance. It is considered by many one of the finest pieces of work of its kind done in Paris in recent years. The mass grouping looking from the Faubourg St. Martin towards the principal façade is very pleasing and effective. The stone carving by M. Margotin should also be noted, as shown, for example, in the photograph of the entrance doorway to the Justices' Court [p. 140]. The front entrance doors are fine examples of modern metal-work.

The district in which this Mairie is placed seems a poor one, and the neglect which is so noticeable in the building is much to be deplored.

The warming of the building is effected by low pressure steam with pipes concealed

PORTION OF ENTRANCE FRONT, MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS.

CENTRAL RECEPTION HALL, MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS.

behind window backs, &c., as at the Hôtel de Ville. No special provision appears to have been made for extract ventilation.

According to M. Dulong, there is nothing of special constructive interest in the building: the floors are of iron construction combined with brick or plaster, as in most Parisian structures.

The cost of the building amounted to nearly 3,000,000 francs.

N.B.—Since the above notes were written the following note has appeared in *The Builder* relative to the decorative completion of this Mairie:—"The Municipal Council have now taken the matter up, and have selected the artists who are to put the finishing touches to the building. The two principal fronts are to be decorated with eight stone statues symbolising the principal industries of the quarter. Those on the façade towards the

Faubourg St. Martin are to represent river navigation, glass work, embroidery, and ceramic ware: these will be executed by MM. Barrau, Démaille, Morcel, and Larche. The four on the façade towards the Rue du Château d'Eau are to represent silversmith's work, artificial flowers, perfumery, and theatrical art. They will be executed by MM. Carlus, Caussé, Crétien, and Gaston Leroux. In the interior M. Henri Martin is to take in hand the large panel in the Salle des Mariages, and a number of other artists, among whom are MM. Paul Badouin and Béroud, are to paint the vertical panels and the ceilings of the two rooms which adjoin the Salle des Fêtes. A sum of 118,000 francs has been voted for the work."

As no mention is here made of the Salle des Fêtes itself, the painted decorations for this room are apparently not covered by the present scheme.
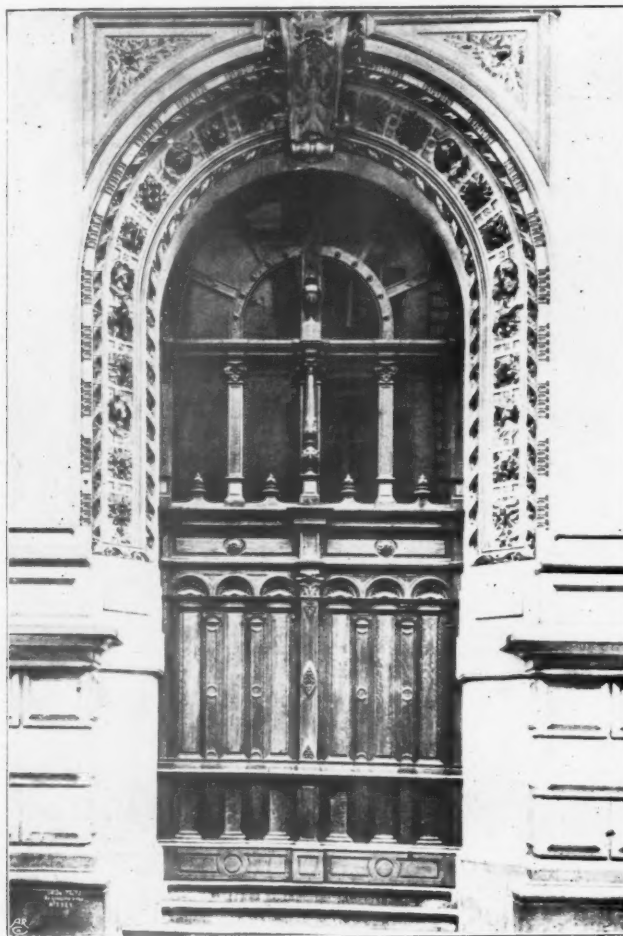
DOORWAY TO JUSTICES' COURT, MAIRIE OF THE TENTH ARRONDISSEMENT, PARIS.

(To be continued.)